# A toolkit for integrated vector management in sub-Saharan Africa

# 1 Contents

# Preface

This tool kit for Integrated Vector Management (IVM) is designed to help National and Regional Level programme managers, to design and run large IVM programmes. This toolkit is an extension of earlier guidance and teaching material provided by the World Health Organisation (WHO). In particular it complements a series of WHO guidance documents published in 2012; *Handbook for IVM, Monitoring and Evaluation Indicators for IVM, Guidance on policy-making for IVM*, and *Core structure for training curricula on IVM*.

This Toolkit is aimed at the vector control programme manager working at the **National or Regional level.** It provides the **technical detail** required in order to plan, implement and monitor and evaluate an IVM approach to vector control. IVM can be utilised where the aim is **control** or **elimination** of VBDs and can also contribute to **reducing the development of insecticide resistance**. We link to existing guidance documents where relevant, provide guidance on where VBD are endemic and what interventions should be implemented, give case studies on various aspects of IVM and highlight key points of note throughout the document.

**In terms of diseases, this toolkit focuses on malaria, lymphatic filariasis, dengue, leishmaniasis, onchocerciasis, human African trypanosomiasis and schistosomiasis. To a lesser extent it also includes information on other viral diseases (Rift Valley fever, West Nile fever, chikungunya, yellow fever) and trachoma. Other vector-borne disease may become apparent in your particular country or area and vector control using an IVM approach should be adopted for these diseases as per national priorities.** There is a strong malaria focus in this toolkit since malaria is the most important VBD in sub-Saharan Africa. The majority of experience in vector control is on malaria and therefore there is an opportunity for other VBD programmes to learn from these examples.

We hope that the detail provided in this Toolkit will help programme managers design and run effective IVM programmes.

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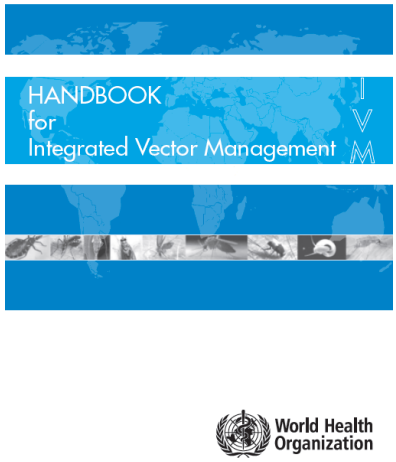
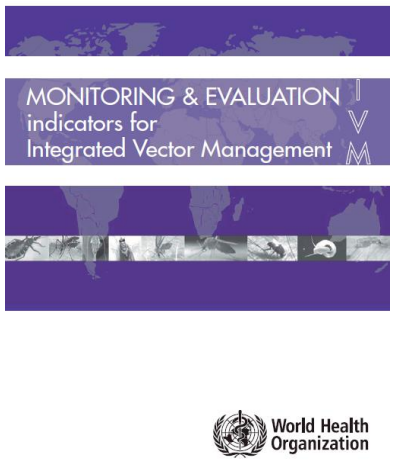
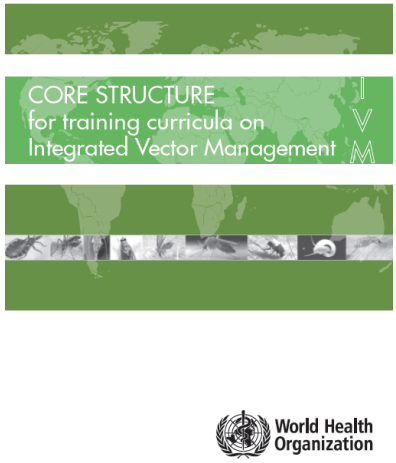
## Key Reference Documents

| | |
|---|---|
| World Health Organization (2012). Handbook for Integrated Vector Management. |  |
| World Health Organization (2012). Monitoring & Evaluation indicators for Integrated Vector Management. |  |
| World Health Organization (2012). Core Structure for Training Curricula on Integrated Vector Management |  |

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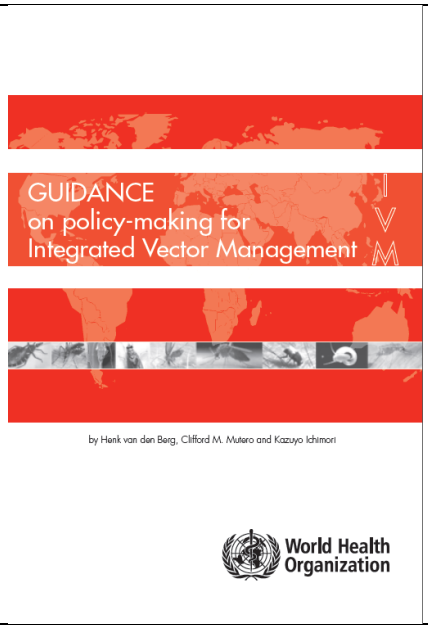
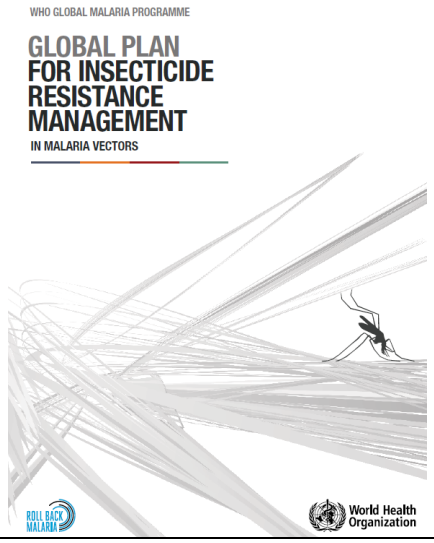
| World Health Organization (2012). Guidance on policy-making for Integrated Vector Management |  |
| WHO Global Malaria Programme (2012) Global Plan for Insecticide Resistance Management in Malaria Vectors. |  |

**Hi, I am Musa!**

**I am a vector control programme manager at the central or regional level of a country. I have too much to do & have few resources available. Please follow my tips if you are in a similar situation to mine.**

# Executive summary

Vector borne diseases (VBD) are infectious diseases transmitted by mosquitoes, ticks, flies and bugs, which act as vectors of the pathogens. VBD contribute substantially to the global burden of disease and disproportionately affect communities living in developing countries. There is a high burden of VBD in sub-Saharan Africa (SSA) and many of these diseases are present in the same geographic location. In this Toolkit we focus on the key VBD affecting populations in SSA: malaria, lymphatic filariasis, dengue, cutaneous leishmaniasis, visceral leishmaniasis, onchocerciasis, human African trypanosomiasis and schistosomiasis. To a lesser extent we include information on other viral diseases (Rift Valley fever, West Nile fever, chikungunya, yellow fever) and trachoma. Other VBD may become apparent in your particular country or area and vector control using an IVM approach should be adopted for these diseases as per national priorities.

Integrated Vector Management (IVM) is a "rational decision-making process for the optimal use of resources for vector control". The aim of the IVM approach is to contribute to achievement of the global targets set for VBD control – whether these targets are control or elimination. IVM does this by making vector control more efficient, cost effective, ecologically sound and sustainable. IVM is characterised by evidence based decision making and collaboration both within the health sector and between sectors. IVM can involve multiple tools against a single VBD or single/multiple vector control tools used in an integrated fashion against multiple VBD. IVM also offers a route by which insecticide resistance in vector populations can be managed.

IVM requires strong political support from central government to succeed, and in particular to foster intra and inter-sectoral collaboration. An IVM Steering Committee (ISC) should be set up with broad participation from stakeholders including government ministries, non-governmental organisations, industry and community organisations. The ISC has oversight for national implementation of IVM and this structure should be replicated at lower administrative levels where necessary. A vector control needs assessment should be carried out to describe for example the policy and institutional framework and resources available for vector control in the country.

IVM is a management system which is flexible and can adapt to local conditions and change. IVM should follow a cyclical process with multiple rounds of situational analysis, planning, design, implementation and monitoring and evaluation. A comprehensive assessment of the disease situation including epidemiological and vector assessment, identification of local determinants of disease and stratification of areas at risk is essential to tailor the IVM programme to the situational context. On the basis of this assessment, knowledge of the efficacy of vector control methods and other considerations such as insecticide resistance and cost effectiveness, vector control interventions should be selected. Needs and resources should be mapped out and implementation strategies planned. Finally, the programme should be monitored and evaluated to determine the effect on the disease of interest and to allow feedback on programme performance to influence future planning and implementation. In subsequent periods, it may be necessary to reassess the local disease situation.

VBD results from the interplay between pathogen, vector, human, animal and environmental determinants. In terms of pathogen-related determinants, it is important to consider which pathogens are responsible for disease in your area and where the diseases are endemic. In terms of

the vector, it is important to determine which vectors are present, where and when they occur, their behavioural characteristics and susceptibility to insecticides. Human-related determinants which should be investigated include; where high risk groups live, local attitudes and practices towards VBDs and access to diagnosis and treatment. Animal-related determinants are those where diseases of humans also infect other animals, such as human African trypanosomiasis, in which case abundance of reservoir hosts needs to be considered. Environmental determinants include local ecosystems, land use, weather patterns and vector breeding sites. It is important to consider these determinants and their interaction to understand why diseases occur and point to ways in which to control them.

Understanding the distribution of VBD and vectors is necessary in order to plan control efforts and prioritise resources. A disease assessment should be conducted in two stages – i) broad-level analysis and stratification (provincial level) and ii) local-level analysis (district and below). A broad-level analysis consists of assessing disease endemicity maps, province-level epidemiological data and vector distributions. Programmes can then classify provinces according to diseases present, their incidence, vector species and ecology. A local level analysis involves assessing the micro-epidemiology of the disease including district / community level epidemiological data, as well as local-level environmental and human determinants.

A wide range of vector control tools exist; which can be broadly classified into chemical-based and non-chemical based tools for control of either adult or immature forms of the vector. It is important to choose vector control tools on the basis of their efficacy primarily against epidemiological parameters (prevalence or incidence of infection/disease) although evidence of efficacy against the vector may be useful in some circumstances. A number of other factors should however, be taken into account when choosing vector control tools since some tools may not be as efficacious or feasible in different environments. These other factors include: vector characteristics, resistance status, human and environmental safety, affordability / cost effectiveness, human resource requirements, community participation / intervention acceptability and product quality / registration.

Resource planning is an essential step. An inventory should be made of the resources and organisational structures available for vector control. Financial, human and technical resources need to be estimated. Costing should generally be conducted at national level based on a strategic plan with clear terms of reference. A number of web-based tools are available for resource planning.

With regards to implementation, there are a number of factors which need to be considered such as when is the best time to implement a particular intervention, areas of implementation and entities involved in implementation and monitoring and evaluation. Items to consider under areas of implementation include populations to be targeted, geographic areas and goals of vector control (i.e. control or elimination). There needs to be strong political leadership and commitment in order for IVM to work. A national intersectoral steering committee should be established to oversee the effective coordination of IVM activities, led by a focal person who will have overall responsibility for the IVM programme country wide. This needs to be accompanied by committees or task forces at lower administrative levels (e.g. district) who have a more hands-on role in planning and implementation. Although the main responsibility for IVM falls on the health sector, it is important to involve different sectors, where possible, including the community. Responsibility for monitoring

and evaluation can fall to external evaluators, or the programme and should be participatory where possible.

In the first instance, it is recommended to introduce interventions for which there is the strongest evidence of efficacy, if this has not already happened. These interventions should be aligned with the local entomological and socio-behavioural parameters. Interventions for which there is more limited evidence should be tested in small scale pilot studies before being rolled out at scale. At a minimum this should be done in two sites, one as a control site and entomological data should be collected both pre- and post-intervention. For interventions which do not have a WHO recommendation, robust trials with epidemiological outcomes need to be performed. These studies require research expertise and so should generally be carried out with the assistance of research institutions.

Vector surveillance should be conducted throughout the life of the IVM programme, although objectives and parameters measured will change depending on the stage of the programme. The most commonly measured parameter is vector density (mature or immature forms), although other parameters are important, particularly insecticide susceptibility. When setting up sentinel sites there are a number of factors which should be considered including disease endemicity, ecological zones, accessibility of the site and use of insecticides in the area. Vector surveillance can be conducted by vector control staff or community involvement is possible with the right training and support. Data management systems need to be set up to manage and integrate the vast quantities of data generated on entomology, cases surveillance, surveys and intervention coverage to allow for effective decision making.

Monitoring and evaluation of the IVM programme is essential to allow programme feedback, measure impacts and increases accountability to stakeholders and donors. A monitoring and evaluation framework should be established with clear indicators by which the programme implementation and success is going to be tracked and measured with clear timescales and sources of date for each indicator. Indicators will be intervention/disease specific, for example number of long-lasting insecticidal nets (LLINs) distributed or effect on disease burden and IVM programme specific, for example number of staff trained in IVM. A robust data management system needs to be set up to capture data on IVM indicators and data/findings should be disseminated regularly.

# Abbreviations

| Acronym | Term |
|---|---|
| ACT | artemisinin combination therapy |
| APOC | African Programme for Onchocerciasis Control |
| Bti | *Bacillus thurigensis israeliensis* |
| CORPs | community-based resource persons |
| DALYs | disability adjusted life years |
| DDT | dichlorodiphenyltrichloroethane |
| DDMS | disease data management system |
| DEC | Diethylcarbamazine citrate |
| DHS | demographic and health surveillance |
| DHSS | demographic and health surveillance sites |
| ELISA | enzyme-linked immunoabsorbent assay |
| FFS | farmer field schools |
| GIS | geographical information systems |
| GPS | global positioning system |
| HAT | human African trypanosomiasis |
| HEW | health extension workers |
| HMIS | health management information system |
| ICER | incremental cost effectiveness ratio |
| IEC | Information education communication |
| IPM | integrated pest management |
| IRM | insecticide resistance management |
| IRS | indoor residual spraying |
| ISC | intersectoral steering committee |
| IVCC | integrated vector control consortium |
| IVM | integrated vector management |
| ITN | Insecticide treated bednet |
| LSTM | Liverpool School of Tropical Medicine |
| MDA | mass drug administration |
| LF | lymphatic filariasis |
| LLINs | long-lasting insecticidal nets |
| LSM | larval source management |
| MICS | multiple indicator cluster surveys |
| MIS | Malaria indicator survey |
| M&E | monitoring and evaluation |
| MFI | Khartoum malaria free initiative |
| MFP | Malaria focal person |
| MoH | Ministry of Health |
| NGO | non-governmental organisation |
| NTD | neglected tropical diseases |
| OCP | Onchocerciasis control programme |
| OPD | outpatients department |
| PCR | polymerase chain reaction |
| PDA | personal digital assistant |
| PMI | Presidents Malaria Initiative |
| PWD | public works department |
| RCT | randomised controlled trial |

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|---|---|
| RDT | rapid diagnosis test |
| REA | rapid epidemiological assessment |
| SIT | sterile insect technique |
| SMS | short message service |
| TCU | ten cell unit |
| TWG | technical working group |
| VBD | vector borne diseases |
| VCNA | Vector control needs assessment |
| WHO | World Health Organisation |
| WHOPES | World Health Organisation Pesticide Evaluation Scheme |
| YLD | years of life lost due to disability |
| YLL | years of life lost through premature death |

# Glossary

| Term | Explanation |
|---|---|
| advocacy | Encouraging uptake of IVM |
| anthropophagic | Feeds predominantly on people |
| anthropophilic | Attracted to people |
| Breteau index | Number of positive containers per 100 houses inspected |
| capacity building | Training experts in IVM |
| case surveillance | Ongoing (routine) collection of data on incidence of disease cases |
| container index | Percentage of water-holding containers infested with larvae or pupae |
| controlled before-and-after study | Trial with a control group in which the outcome of interest (entomological or disease/infection) is measured in the intervention and control arm at timepoint(s) before and after the intervention is implemented. |
| cross resistance | Whereby resistance to one insecticide confers resistance to another insecticide, even when the vector has not been exposed to the latter insecticide |
| decentralisation | Political reform to reduce the extent of central influence and promote local autonomy |
| diurnal | Active during the day |
| exophagic | Vectors that feed outdoors |
| exophilic | Vectors that rest outdoors |
| endophagic | Vectors that feed indoors |
| endophilic | Vectors that enter houses |
| environmental management | Modification and/or manipulation of environmental factors or their interaction with man with a view to preventing or minimising vector propagation and reducing man-vector-pathogen contact. It may entail one of two options (or both): environmental modification (permanent environmental changes) and environmental manipulation (recurrent actions aimed at achieving temporary unfavourable conditions for breeding |
| evaluation | Assessment of a programme to determine whether activities led to expected results in terms of outcomes and impact |
| evidence-based decision making | Making decisions based on evidence, not on what has traditionally been done |
| house index | Percentage of houses infested with larvae and/or pupae |
| Insecticide treated net (ITN) | Bednet impregnated with an insecticide, usually not a long-lasting formulation so requires regular re-treatment |
| intrasectoral | Working within a sector, such as health |
| intersectoral | Working with other sectors, like the department of the environment |
| Long-lasting insecticidal net | Bednet which has been treated with a long-lasting insecticide formulation that is released over an extended period of time (usually 3 years) |
| Logical framework (or logframe) | A tool for improving the planning, implementation, management, monitoring and evaluation of projects and programmes. It is a written plan listing the main elements in a project and highlighting the logical linkages between them. |
| Meta-analysis | Statistical technique used to summarise the results of several studies so that we can obtain an average estimate of how efficacious an intervention is. |
| monitoring | Continuous tracking of programme performance against pre-determined objectives and targets |

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|---|---|
| protective efficacy | Percentage reduction in disease/infection among people who have received an intervention. Protective efficacy is calculated as (1 – risk ratio) x 100. Here, the risk ratio is the risk of disease or infection in the intervention group divided by the control group. Risk ratio can be substituted for rate or odds ratio in this equation. |
| nocturnal | Active during the night |
| randomised controlled trial (RCT) | a trial in which individuals or areas are randomly assigned to receive either the intervention or control. This is the best experimental design used for determining the efficacy of an intervention. |
| social mobilisation | Process that raises awareness and motivates people to demand change towards a particular goal |
| stockouts | Lack of medicine or other commodities in health facilities |
| stratification | Classification of disease endemic areas by their epidemiological and ecological characteristics |
| subsidiarity | Decisions made at the local level |
| systematic review | A review of literature on a particular topic that has been conducted in a systematic fashion so that it is more comprehensive. Usually involves searching databases of publications using defined search terms to find studies. |
| Vector surveillance | Ongoing (routine) collection of entomological data |
| zoophagic | Feeds predominantly on animals |
| zoophilic | Attracted to animals |

# 1 Introduction to IVM for disease control

## 1.1 Why are vector borne diseases important?

Vector borne diseases (VBD) are infectious diseases transmitted by mosquitoes, ticks, flies and bugs, which act as vectors of the pathogens. VBD, such as malaria, dengue, leishmaniasis, lymphatic filariasis, schistosomiasis and human African trypanosomiasis contribute significantly to the global burden of disease and disproportionately affect communities living in developing countries in tropical and sub-tropical zones. The most important VBD is malaria; in 2013, the World Health Organisation (WHO) estimates that in the African region there were 165 million cases of malaria, which caused approximately 562,000 malaria deaths [1] (Table 1.1)[1]. Other VBD such as lymphatic filariasis and onchocerciasis are less deadly but still result in high levels of morbidity in sub-Saharan Africa (SSA) [2, 3]. Dengue fever, together with associated dengue haemorrhagic fever, is the world's fastest growing vector borne disease and cases are becoming more widespread in SSA [4]. As well as their effect on public health, VBD are a major cause of poverty and underdevelopment in many countries [5].

**Table 1.1: Burden of vector borne diseases in sub-Saharan Africa in 2010** [6]

| Disease | Deaths (thousands) and 95% uncertainty interval | DALYS (thousands) and 95% uncertainty interval |
|---|---|---|
| Malaria | 1,057,078 (767,151 - 1,455,010) | 76,631,962 (53,331,245 - 107,461,725) |
| Lymphatic filariasis | 0 | 987,424 (632,562 - 1,446,703) |
| Dengue | 1,395 (265 – 4,010) | 89,099 (16,359 - 266,309) |
| Leishmaniasis | 10,332 (5,712 - 17,383) | 733,211 (401,599 - 1,256,985) |
| Onchocerciasis | 0 | 494,038 (358,843 - 655,985) |
| Human African trypanosomiasis | 9,111 (954 – 28,994) | 560,281 (69,068 - 1,765,404) |
| Schistosomiasis | 62 (0 – 363) | 2,799,078 (1,450,723 – 5,279,366) |
| Trachoma | 0 | 53,131 (36,966 – 73,587) |

VBD are widespread throughout SSA and in many cases diseases are co-endemic, i.e. co-exist in the same geographic area. Figure 1.1 indicates the geographic distribution of nine major VBD (falciparum and vivax malaria, lymphatic filariasis, dengue, cutaneous leishmaniasis, visceral leishmaniasis, onchocerciasis, human African trypanosomiasis and yellow fever). In some areas of SSA all eight of these VBD are co-endemic.

[1] This WHO estimate for malaria differs from that calculated by in the Global Burden of Disease project (presented in Table 1.1) due to the different models used.

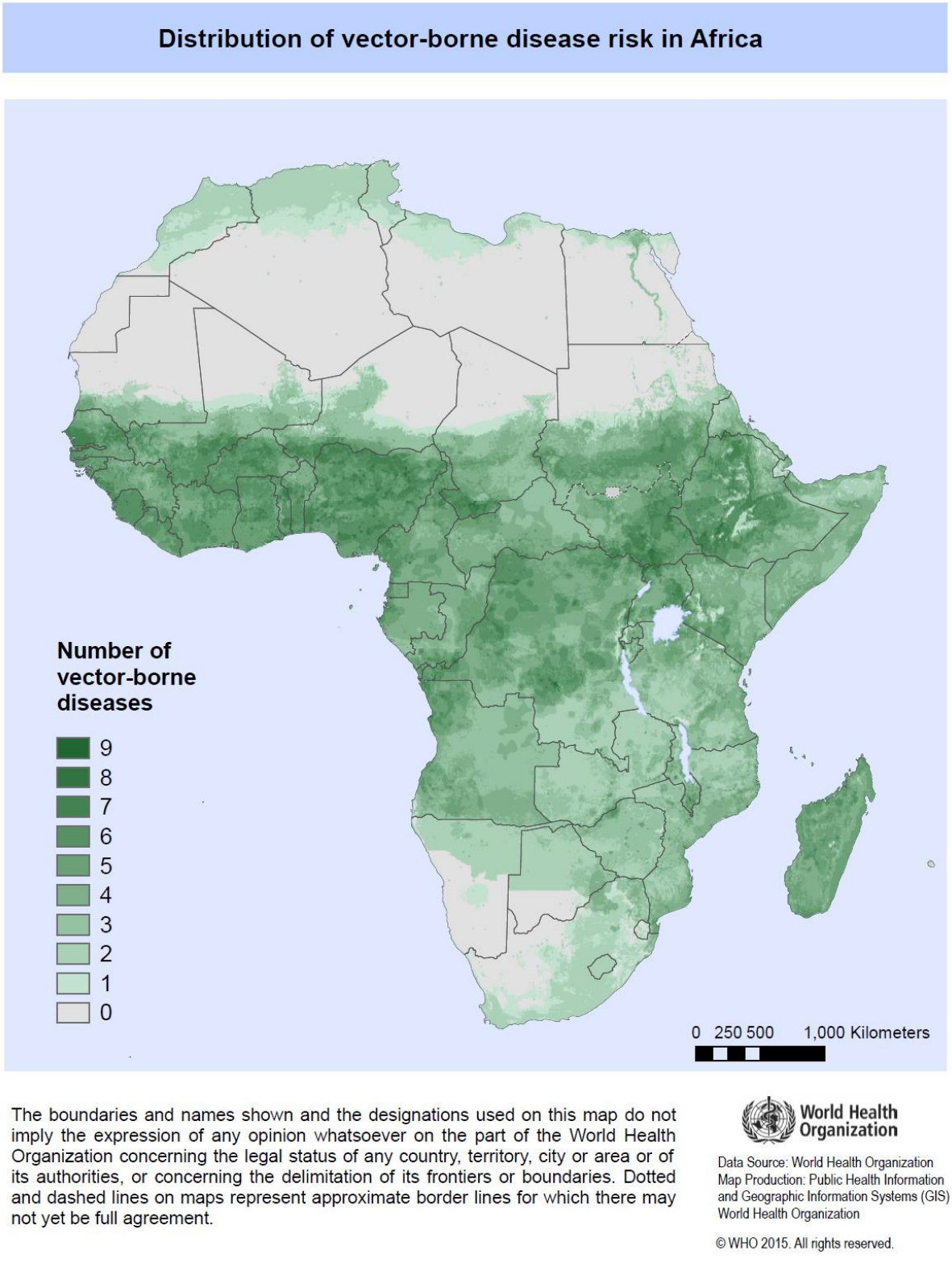



**Figure 1.1: The global distribution of combined infection risk from nine major vector-borne diseases (falciparum and vivax malaria, lymphatic filariasis, dengue, onchocerciasis, cutaneous and visceral leishmaniasis, human African trypanosomiasis and yellow fever)**. Areas in colour are at risk from at least one disease and the number of diseases posing a risk is indicated by the colour scale.

## 1.2 IVM for disease control

Integrated Vector Management (IVM) is a "rational decision-making process for the optimal use of resources for vector control" [7]. The aim of the IVM approach is to contribute to achievement of the global targets set for vector-borne disease control or elimination, by making vector control more efficient, cost effective, ecologically sound and sustainable. In essence IVM is a multi-pronged adaptive management approach against VBDs.

Vector control programmes currently face a number of challenges including dwindling public sector human and financial resources, the threat of insecticide resistant vectors, emergence of new VBD and pressure to lessen the environmental impact of vector control. IVM can help address these challenges. IVM can increase effectiveness of vector control by encouraging vector control programmes to use more local evidence to improve the choice and targeting of vector control approaches, to integrate interventions where appropriate and to collaborate both within the health sector and with other sectors. Rather than vector control programmes with a single disease focus working alone, by collaborating together duplication and overlap can be reduced and costs saved by making better use of existing human and financial resources. By broadening the range of tools used by vector control programmes, such as environmental management, encouraging use of different insecticide classes to attack different life stages of the vector and monitoring the effect of interventions on insecticide susceptibility, IVM may be able to mitigate the threat of insecticide resistance. In addition, many countries are facing the emergence of new VBD and the rise of viral VBD such as dengue and chikungunya. IVM can potentially help VBD control programmes to increase preparedness for disease introduction or re-introduction through integrated vector and case surveillance. Use of non-insecticide based control measures may also help to lessen the environmental repercussions of chemical vector control.

The World Health Organisation (WHO) highlighted the five major elements of an IVM strategy as i) an integrated approach, ii) evidence-based decision making, iii) collaboration within the health sector and with other sectors, iv) advocacy, social mobilisation and legislation, and v) capacity building [8] (summarised in Table 1.2).

**Table 1.2: Key elements of an integrated vector management (IVM) strategy (adapted from [9])**

| | Element | Description |
|---|---|---|
| 1 | Integrated approach | • Addresses several diseases using vector control tools, often in combination and synergistically<br>• Utilises chemical and non-chemical vector control methods<br>• Integrates with other disease control methods, such as drugs and vaccines |
| 2 | Evidence-based decision making | • Strategies and interventions are adapted to local vector ecology and disease epidemiology and are guided by operational research, surveillance and monitoring and evaluation. |
| 3 | Intra- and intersectoral collaboration | • Collaboration within the health sector and with other sectors (public and private)<br>• Planning and decision-making delegated to lowest possible level (subsidiarity) |
| 4 | Advocacy, social | • Principles of IVM promoted and integrated into policies in all |

| | | |
|---|---|---|
| | mobilisation and legislation | relevant ministries, organisations and civil society<br>• Establishment / strengthening of regulatory and legislative controls for public health<br>• Community engagement and empowerment to increase sustainability |
| 5 | Capacity building | • Availability of adequately trained infrastructure, financial and human resources at central and local level<br>• Training and education in place according to IVM curricula |

i) Integrated approach:

IVM involves the use of a range of proven vector control methods used either alone or in combination. IVM involves use of multiple vector control methods against a single disease or a single method or multiple methods against multiple diseases (Figure 1.2). Methods can be chemical or non-chemical. IVM can also supplement vaccines, mass drug administration or diagnosis and treatment for integrated disease control.

IVM, in certain situations, is able to address several diseases concurrently because some vectors can transmit several diseases (e.g. *Anopheles gambiae* can transmit both malaria and lymphatic filariasis, LF) and some interventions are effective against several vectors (e.g. Long lasting insecticidal nets (LLINs) are effective against malaria, lymphatic filariasis and leishmaniasis vectors).

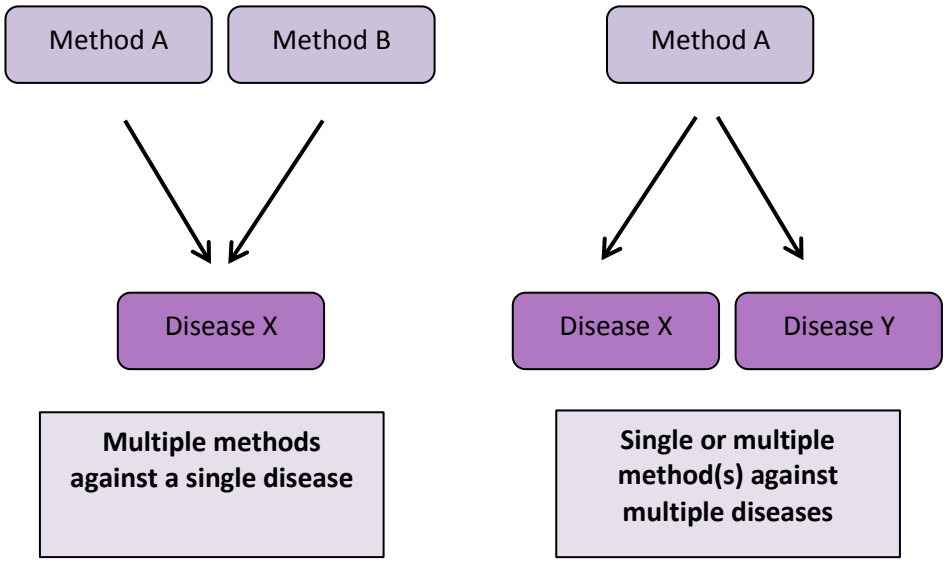



**Figure 1.2: Schematic showing use of vector control methods for IVM**

ii) Evidence-based decision making

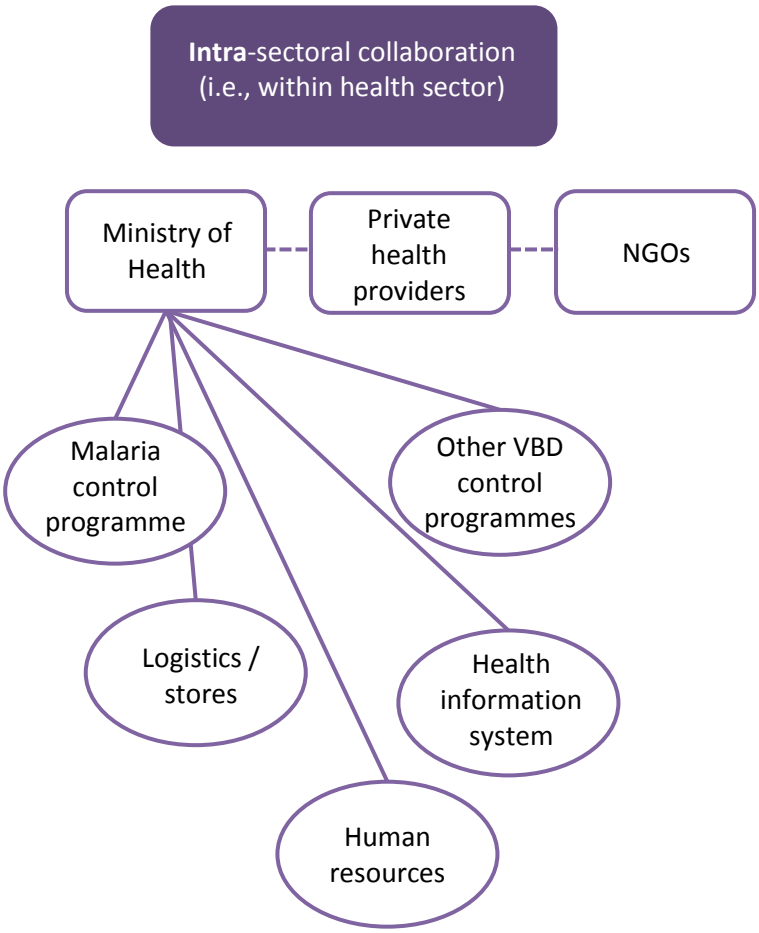
Selection and implementation of vector control methods should be guided based on knowledge of the local vector ecology and epidemiological situation. IVM programmes should be accompanied by monitoring and evaluation of the effect on both the vector and disease which serve to troubleshoot implementation and evaluate the impact of the programme. In addition, operational research priorities should also be identified and studies conducted to inform the programme.

**KEY POINT**

IVM can be used as a strategy for a variety of programme goals – whether the goal is control or elimination

iii) Collaboration within the health sector and with other sectors

IVM should be a collaborative effort involving cooperation both within the health sectors and with other sectors such as government ministries (e.g. agriculture, education, housing and public works), local government, community groups and non-governmental organisations (NGOs) (Figure 1.3). Intra- and intersectoral collaboration should be coordinated by an IVM Steering Committee (ISC) comprising stakeholders from different ministries, local government, industry, research/academic institutions, NGOs/civil society and community organisations.



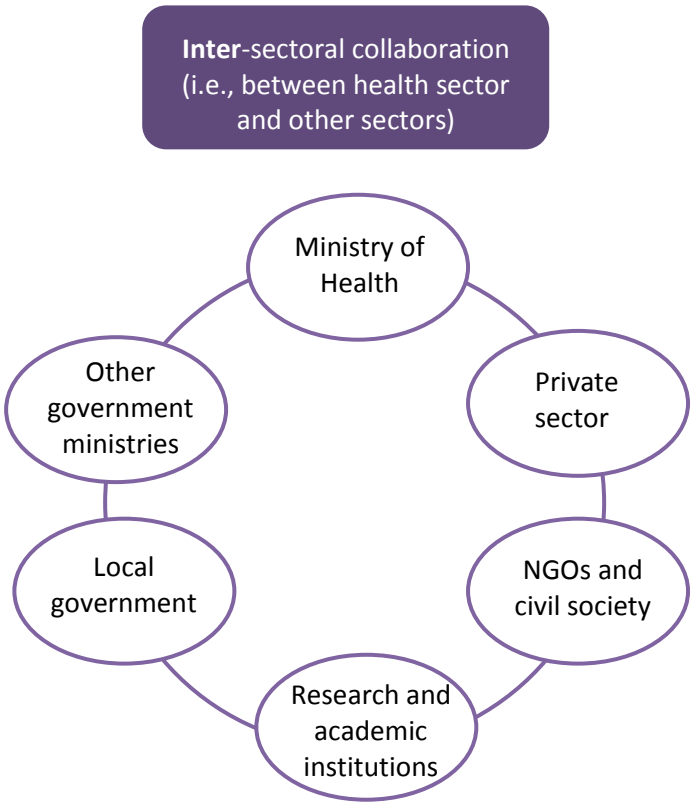



**Figure 1.3: Hypothetical example of ministries/organisations involved in intra- and intersectoral collaboration in IVM**

iv) Advocacy, social mobilisation and legislation

IVM needs to be communicated effectively, promoted and integrated into policies in relevant ministries, organisations and civil society. Regulatory and legislative controls for public health need to be established or strengthened. Involvement and engagement of communities can help to increase the sustainability of IVM. Communities need to be made aware of the risks of VBD and take action themselves whether this is use of preventive measures or vector control in their peri-domestic environment.

v) Capacity building

IVM relies on the availability of skilled personnel at national, sub-national, district and village level and therefore needs to be accompanied by a capacity building programme to upgrade and maintain the knowledge and skills of these personnel.

## 1.3 IVM over time

IVM should be seen as a dynamic, adaptive process since the relative importance of different VBDS will change over time as illustrated in Figure 1.4. For example lymphatic filariasis is maintained only in areas of extremely high transmission. Long-term suppression of transmission should result in the elimination of lymphatic filariasis well before malaria is eliminated. As malaria declines within a town or city, shrinking to the edge, dengue may be identified as the preeminent VBD. Vector control

programmes move from widespread control to focal control. Eventually as development takes place dengue is better controlled and mosquito abatement becomes the major theme of vector control agencies to reduce the biting nuisance of vectors and to provide a platform against emerging VBDs. Such a pathway has occurred in the southern states of the United States over the last century. It is important to keep pressure on using vector control in order to prevent re-introduction of disease.

**Figure 1.4 Potential scenario of changing disease dynamics with effective control**


**CHAPTER SUMMARY**

- There is a high burden of vector borne diseases in sub-Saharan Africa and many of these diseases are present in the same geographic location.
- IVM is an approach that aims to make vector control more efficient, cost effective, ecologically sound and sustainable.
- IVM is characterised by evidence based decision making and collaboration both within the health sector and between sectors.
- IVM can be multiple tools directed against a single disease or single/multiple tools implemented in an integrated fashion against multiple diseases.
- IVM is a dynamic approach which can be adapted over time to respond to changing vectors and diseases.

# 2 Framework for planning and implementation of IVM

## 2.1 What are the steps required in order to do IVM?

IVM should follow a cyclical process with multiple rounds of situational analysis, planning, design, implementation and monitoring and evaluation (Figure 2.1). A comprehensive assessment of the disease situation including epidemiological and vector assessment, identification of local determinants of disease and stratification of areas at risk is essential to tailor the IVM programme to the situational context. On the basis of this assessment, knowledge of the efficacy of vector control methods and other considerations such as insecticide resistance and cost effectiveness, vector control interventions should be selected. Needs and resources should be mapped out and implementation strategies planned. Finally, the programme should be monitored and evaluated to determine the effect on the disease of interest and to allow feedback on programme performance to influence future planning and implementation. In subsequent periods, it may be necessary to reassess the local disease situation.

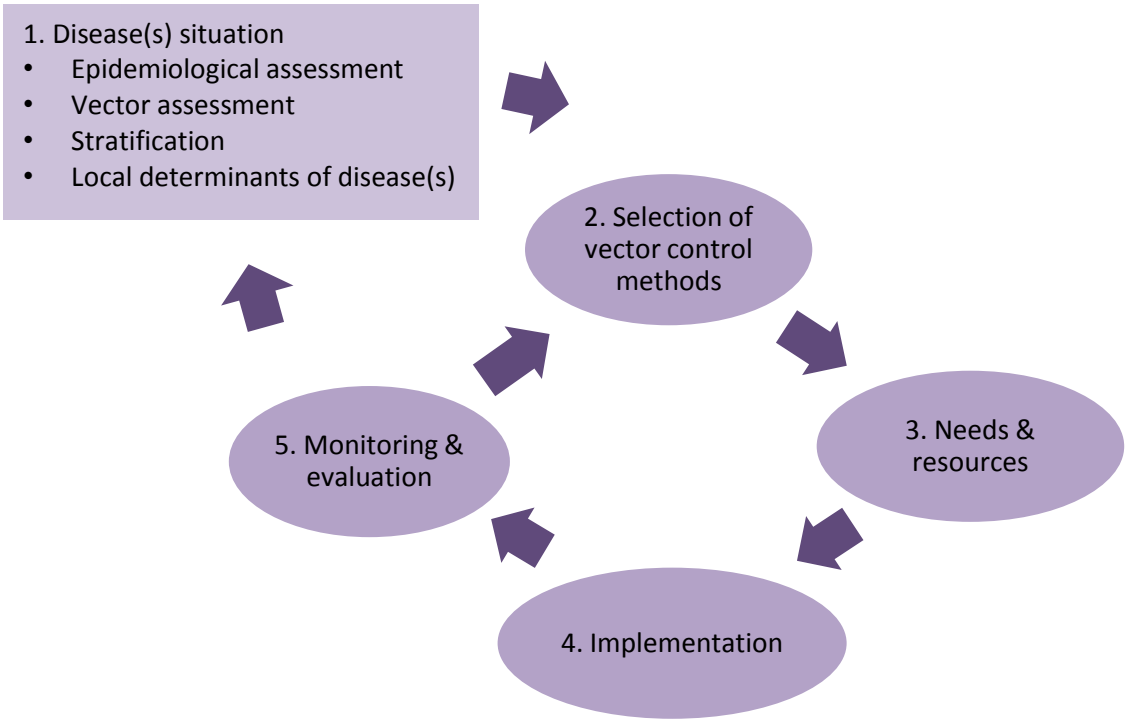



**Figure 2.1: Schematic indicating steps in IVM implementation and monitoring & evaluation feedback loop (modified from WHO 2012[10]).**

**KEY POINT**

Figure 2.1 is the most important in the Toolkit because it shows the steps required to implement IVM. Each step is explained later in the Toolkit

## 2.2 Organisational structures to support IVM

IVM will only work if there is strong political will and support at the Government level. Political commitment will only be forthcoming if a strong case is made for VBD affecting economic development. Therefore, a strong advocacy case needs to be built including information on the burden of VBD, the health, economic, social and cultural impacts of VBD (e.g. absenteeism from school and employment), effectiveness of IVM, benefits of inter-sectoral collaboration, cost effectiveness of IVM and potential cost savings. This is a long term strategy which needs political commitment in order to be sustainable as IVM will evolve over time as patterns of vectors and disease change.

Senior politicians must be involved to establish and sustain a programme and ensure that intrasectoral, and particularly intersectoral collaboration occurs. For this reason IVM programmes need to be approved by the Government and run through the Department of Health in collaboration with other stakeholders since the main aim is to reduce morbidity and mortality of VBDs.

IVM will only work if there is strong political commitment from the outset. Strong messages advocating for integrated VBD control need to be relayed to the government and other stakeholders.

A National IVM steering committee (ISC) needs to be established consisting of senior members of the Ministry of Health, coordinators of disease specific programmes (e.g. malaria, neglected tropical diseases (NTDs), Onchocerciasis Control Programme etc.,), representatives of other Government ministries (e.g. Ministry of Agriculture, Education, Public works etc.,), National Regulatory Authorities, local government, the private sector (including manufacturers, oil and mining companies etc.,), academic and medical research institutions and other interested parties (e.g. non-governmental organisations (NGOs)/civil society groups) (Figure 2.2). Note that this is not an exhaustive list and the representatives on the ISC will differ depending on the country context. Strong advocacy from the Ministry of Health is required to get the commitment of the other line ministries and stakeholders – focusing on increasing the awareness of their contribution and the responsibilities towards VBD and VBD control. For example, the Ministry of Trade and Finance may have an impact on control measures for VBD through import taxes and tariffs on insecticides and LLINs. Research institutions can assist in the evaluation of vector control interventions. Representation from the regions on the national ISC is important to increase knowledge sharing between the regions and national level and gain buy-in to activities. The ISC should be chaired by the Minister of Health and should meet on a regular basis. The ISC should have defined terms of reference (ToR) which outline the roles and responsibilities of the members. It is a good idea to set minimum terms for participation in the ISC and meetings to ensure that there are few changes in membership of the ISC and more continuity. Under the ISC, technical working groups with specific

expertise could be set up with specific terms of reference, for example to discuss capacity-building or monitoring and evaluation.

**KEY POINT**

It is essential that a steering committee is set up to oversee the IVM programme. The committee should comprise members of the different disease control programmes, as well as representatives of other sectors.

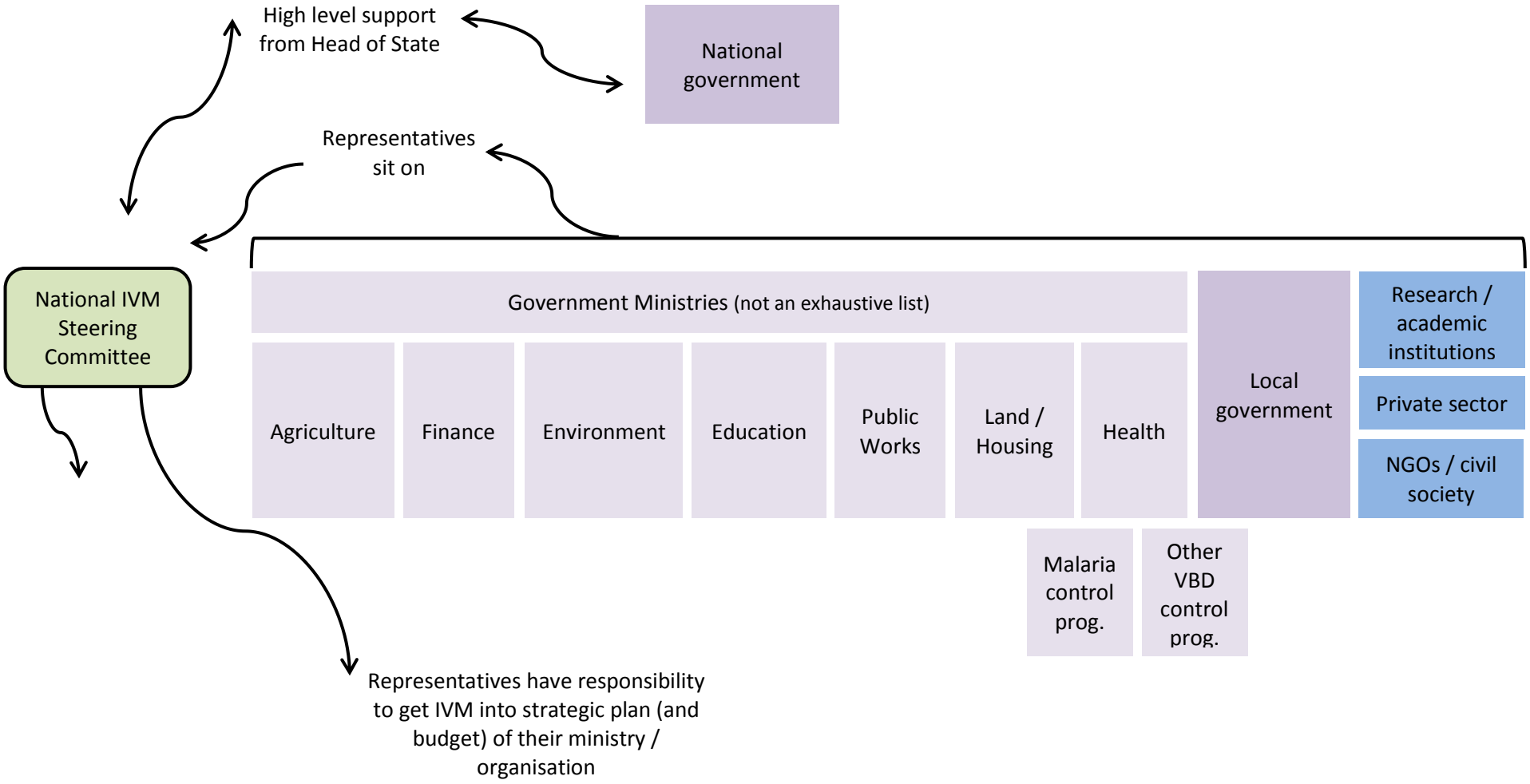
The work of the ISC should be guided by a high level IVM strategic plan. The first version of the IVM strategic plan should be prepared by the Ministry of Health and this can then be evaluated and reviewed by the other stakeholders. In this plan the following should be outlined; the roles and responsibilities of relevant stakeholders, situation analysis and implementation strategy, cost implications, sources of funding and funding structure, summary of monitoring and evaluation (M&E) plan and how to ensure sustainability.

The representatives of each of the ministries/organisations sitting on the ISC are then responsible for taking this high level IVM strategic plan and advocating for IVM and ensuring that IVM is placed in the strategic plans for their own ministries/organisations. This will help the stakeholder to advocate for funding and allocation of other resources (e.g. human resources or materials) to IVM. It may therefore be helpful to make sure the first IVM strategic plan is in place 6 months to 1 year before the strategic plan revision cycles of the individual ministries (usually every 5 years). Based on the individual strategic plans for the ministries/organisations, each line ministry (and other stakeholders) should allocate monies for IVM activities.

In small countries such as The Gambia, the ISC could be backed up by IVM Focal Persons in each region. However, in large countries such as Nigeria with decentralised government then the ISC shown in Figure 2.2 should be replicated at regional level – with representation from line ministries and other organisations working at regional level. At the regional level, the ISC should therefore also be comprised of representatives of the regional ministries and organisations and led by a Focal Person. At district level in large countries, an IVM Focal Person should be assigned. The IVM Focal Persons at regional or district level are responsible for coordination and for driving the IVM programme forward in their region or district. They should work closely with the VBD control programmes in their area and so have a strong awareness of vector control needs. The IVM Focal Persons are also responsible for identifying opportunities for inter-sectoral collaboration, bringing VBD control programmes together and increasing community awareness and participation in vector control. At all levels but particularly at the level of the IVM Focal Person in the regions or district it is important to identify stakeholder in the project. A simple stakeholder analysis tool which could be used by programmes to identify stakeholders as well as their interests, power and influence, allowing formulation of a stakeholder participation strategy can be found in Appendix 1.

Box 2.1 outlines some key tips on governance and planning to support the IVM programme in Morocco.

**Figure 2.2: Schematic showing governance arrangements to support IVM programmes**



**Box 2.1: Structures and planning for IVM – the Moroccan experience and lessons learnt**

**1. It is essential to establish a National IVM Steering Committee.**

With the support of WHO, the Ministry of Health, Morocco adopted the IVM approach in 2005, with the establishment of a National IVM steering committee to strengthen collaboration among relevant ministries and coordination between the organizational structures within the Ministry of Health. The committee is composed of representatives from key line ministries such as agriculture, environment, interior and health and an academic institution.

**2. The National IVM Steering Committee should have defined terms of reference.**

The National IVM Committee has clearly defined terms of reference which cover the study of all aspects of vector control; standardization of control methods; coordination of the actions of the various departments with the management at the national level and oversight of projects to promote the implementation of IVM.

**3. The National IVM Steering Committee needs strong leadership with expertise in and ability to advocate for VBD.**

The Head of Department of Vector Control, acts as the national focal point of IVM and is under the authority of the Chief of the Division of Environmental Health, the Presidency and the secretariat of the committee.

**4. The IVM Committee should undertake a vector control needs assessment prior to preparing an IVM strategic plan**

The IVM committee has conducted a situation analysis and identification of needs in 2007 and consequently prepared a national plan of action of IVM for the period 2008-2012. The IVM strategy has gradually been implemented in several provinces, through awareness of the authorities and local authorities, decentralized services of the ministries concerned, local associations and the local committees of the IVM.

**5. It is beneficial to replicate the IVM Steering Committee at lower levels incorporating locally active stakeholders such as civil society and local government.**

IVM Steering Committees are also replicated at Regional and Provincial levels. The functions of Provincial and local IVM committees are as follows: advocacy and awareness of IVM; situation analysis and needs assessment; planning and implementation of interventions; the appropriate selection of control methods; resource mobilization; monitoring and evaluation of the impact of IVM; capacity building (training, studies, etc.,). The decentralized services of the Ministries of Agriculture, Interior, Environment, Education and Health and the civil society are represented in these committees. An IVM manual was developed in 2012 and distributed to all regions and provinces to give guidance on the process to adopt IVM at the decentralised level.

**6. Take advantage of opportunities for advocacy in support of IVM**

The opportunity of the celebration of World Health Day 2014 themed around VBDs was taken to institutionalise the national, regional and provincial committees by a decision signed by several key Ministers : the Minister of Health, Minister of the Environment and Minister of the Interior.

## 2.3 Vector Control Needs Assessment (VCNA) and other needs assessments

The vector control needs assessment (VCNA) process is established in many countries in sub-Saharan Africa (SSA) [11, 12] and there may be other needs assessments which have been carried out for specific diseases such as those conducted under the auspices of Roll Back Malaria. The VCNA is useful in helping countries to describe the policy and institutional framework within which vector control decision making takes place, the institutional arrangements that support the vector control programme, the management procedures leading to vector control operations and the resource base which supports these operations. We therefore recommend that countries undertake the VCNA situation analysis or revisit this process if it was conducted some time ago.

The VCNA involves conducting a situation analysis, an assessment of bottlenecks that constrain implementation of vector control and a needs assessment. The process and items which should be considered in a VCNA are shown in Table 2.1.

**Table 2.1: Vector control needs assessment – situation analysis and needs assessment – what should be considered? [11, 12]**

| **Situation analysis** | | |
|---|---|---|
| **Area** | | **What should be considered?** |
| Policy and institutional framework for vector control | | General health sector policies<br>Policies by VBD control programmes<br>Non-health sector policies |
| Structures, resources and functions | within the health sector | Place and structure of vector control<br>Inter/intra-sectoral collaboration and coordination<br>Communication and information flow<br>Human resources<br>Financial resources<br>Infrastructure (research/training/technical and operational facilities) |
| | other sectors | |
| Vector control planning and implementation | | VBD burden distribution and vectors<br>Tools, methods, strategies and coverage<br>Pesticide management needs, safety and environmental issues<br>Intra-inter-sectoral collaboration<br>Community mobilisation |

| **Needs assessment** |
|---|
| Opportunities for Strengthening Policy for IVM<br>Opportunities for strengthening institutional frameworks for IVM<br>Strengthening human resources and systems for vector control<br>Leadership and Governance<br>Sustainable Financing for IVM<br>Strengthening Information Systems for IVM<br>Enhancing Implementation: Tools, technologies and logistics<br>Opportunities for community mobilization |

The situation analysis describes the policy framework, management procedures, institutional arrangements structures, resources and functions supporting vector control activities. These items should be assessed at national, regional and district level. The situation analysis also includes a brief assessment of VBD burden, distribution and vectors. It is important to note however, that the sections in this toolkit on evaluating the current epidemiological situation and vector bionomics (e.g. ecology, insecticide resistance) go into much more detail than the VCNA and so should be referred to fully given the importance of this aspect for evidence-based vector control.

Based on information collected in situation analysis, bottlenecks that constrain implementation of vector control and specific needs can be identified. The needs assessment covers for example policy needs (to generate an enabling environment for vector control), institution building needs (strengthen structures for effective delivery of interventions), managerial needs (decision making capacity and leadership), human and financial resources.

**CHAPTER SUMMARY**

- IVM should follow a cyclical process with multiple rounds of situational analysis, planning, design, implementation and monitoring and evaluation.
- Advocacy is needed to gain strong political commitment and support for VBD control and IVM.
- A National IVM Steering Committee (ISC) should be set up with oversight for national implementation of IVM; this structure should be replicated at lower administrative levels where necessary.
- The national ISC should develop a high level strategic plan and stakeholders sitting on the ISC should take responsibility for getting specific activities on his plan into their own strategic plans and budgets.
- The ISC should identify opportunities for inter-sectoral action in planning and implementation of IVM.
- A vector control needs assessment should be carried out to describe for example the policy and institutional framework and resources available for vector control in the country.

# 3 Disease situation analysis

## 3.1 Introduction

It is important to understand the distribution of vector borne diseases (VBDs) and vectors in order to plan control efforts and prioritise resources. An epidemiological assessment requires data primarily showing where the VBDs are endemic. Disease endemicity is determined by four or five factors; the pathogen, vector, human, environmental and in some case animal determinants, which all need to be considered by programme managers. You can find more information on these determinants in Appendix 2.

A flowchart which walks through the steps on how this information should be gathered and integrated is shown in Figure 3.1. This flowchart splits activities into those which should be conducted at broad level (national and first administrative level - region) and local level (district and below). A broad-level analysis is needed to stratify areas of the country according to diseases present and disease incidence, or risk of infection even if cases have not been reported from the area, vector species and ecology. At a more local level, the micro-epidemiology of the disease, including human determinants of VBD should be explored.

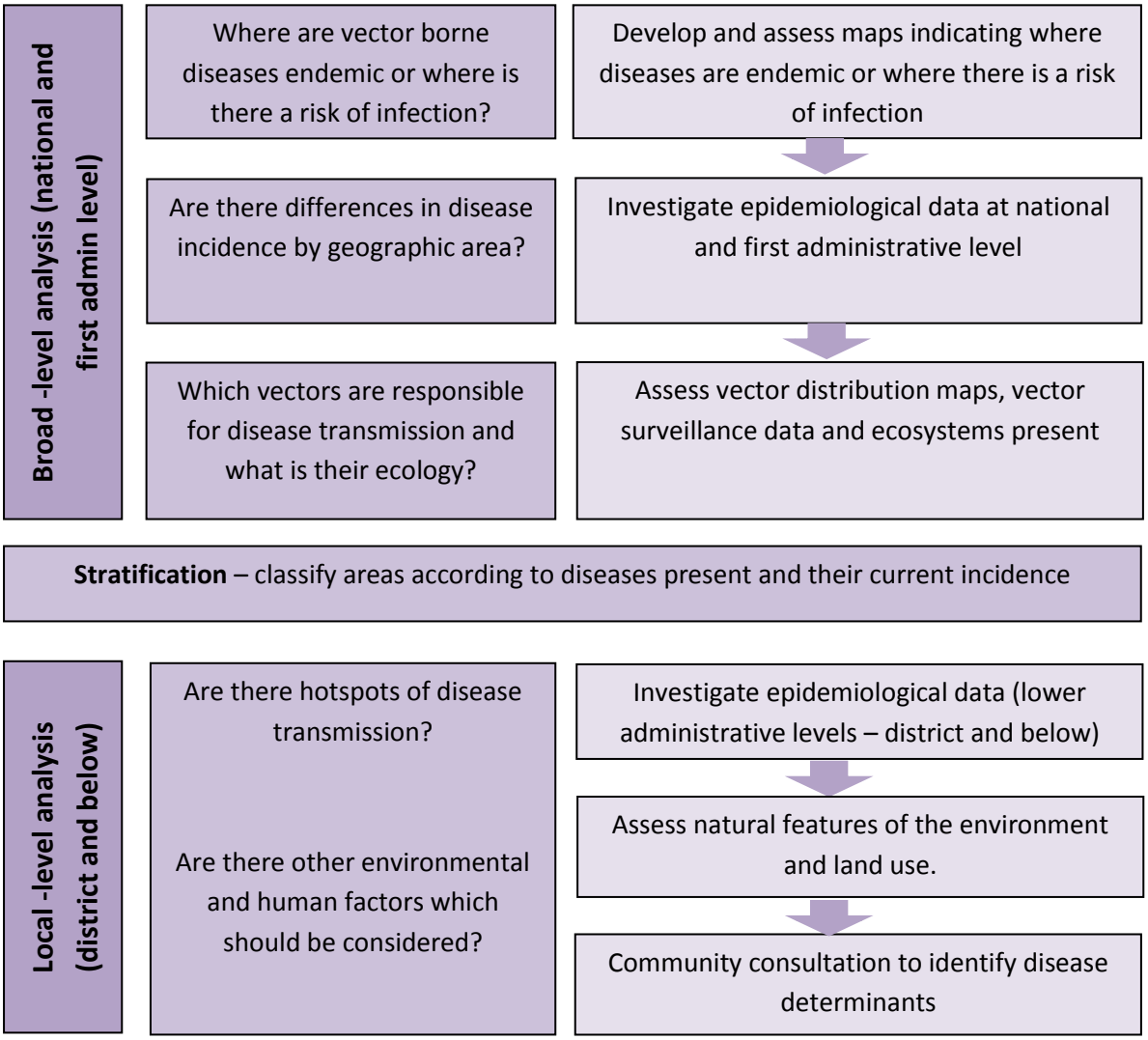



**Figure 3.1: Flowchart indicating steps in conducting disease assessment**

## 3.2 Broad-level analysis

**CONSIDER:**

1. **Which vector borne diseases are endemic and where are cases occurring? Or where is there a risk of infection?**
2. **Are some diseases or infections co-endemic, and if so, where are they found?**
3. **Are there differences in disease risk by geographic area?**
4. **Which vectors are responsible for transmission and where are they found?**

### 3.2.1 Step 1: Examine disease endemicity maps

Maps have been produced which indicate the likely geographic distribution of **risk of infection** with nine major vector borne pathogens; falciparum and vivax malaria, lymphatic filariasis (LF), cutaneous leishmaniasis, visceral leishmaniasis, dengue, human African trypanosomiasis (HAT), onchocerciasis and yellow fever (Figure 3.2, 3.3, 3.6- 3.12). For *Plasmodium falciparum* and *P. vivax*, malaria maps are available which represent more epidemiologically relevant quantities, such as the parasite rate or case incidence rate [13].

For some of these diseases (falciparum and vivax malaria, LF and onchocerciasis) the maps are likely to be reliable since a large amount of information on sub-national disease endemicity was used to generate them. For dengue and leishmaniasis the predicted extents of the maps are less certain. For yellow fever very little information was available and this map should therefore be considered only a very rough estimate of the extents of infection risk (the map is likely to overestimate the area at risk of infection).

While the maps show the distribution of infection risk for each disease, it is important to note that diseases/infections may also be co-endemic i.e. more than one disease/infection is present in a particular geographic area. Therefore, you may need to look at the maps side by side to work out whether populations in areas of your country are at risk of more than one infection.

Maps of other VBDs are available. Schistosomiasis infections cannot be accurately predicted on a broad scale. This is because infections are highly focal as transmission requires contamination of freshwater bodies by infected people urinating in water bodies or defaecating in the open, specific freshwater snails as intermediate hosts, and human water contact. Maps indicating where schistosomiasis surveys have been done and the information on parasitological prevalence (presence of schistosome eggs in urine or stool samples) or blood in the urine are available for individual countries at http://www.thiswormyworld.org [14]. Maps illustrating the distribution of trachoma (active trachoma in children aged 1-9 years and trichiasis in adults) can be found at http://www.trachomaatlas.org [15].

Unfortunately, there is limited information on the distribution of other mosquito borne viral diseases such as chikungunya, Rift Valley fever, West Nile virus and O'nyong-nyong in sub-Saharan Africa and so we are not currently aware of any maps illustrating infection risk for these diseases.

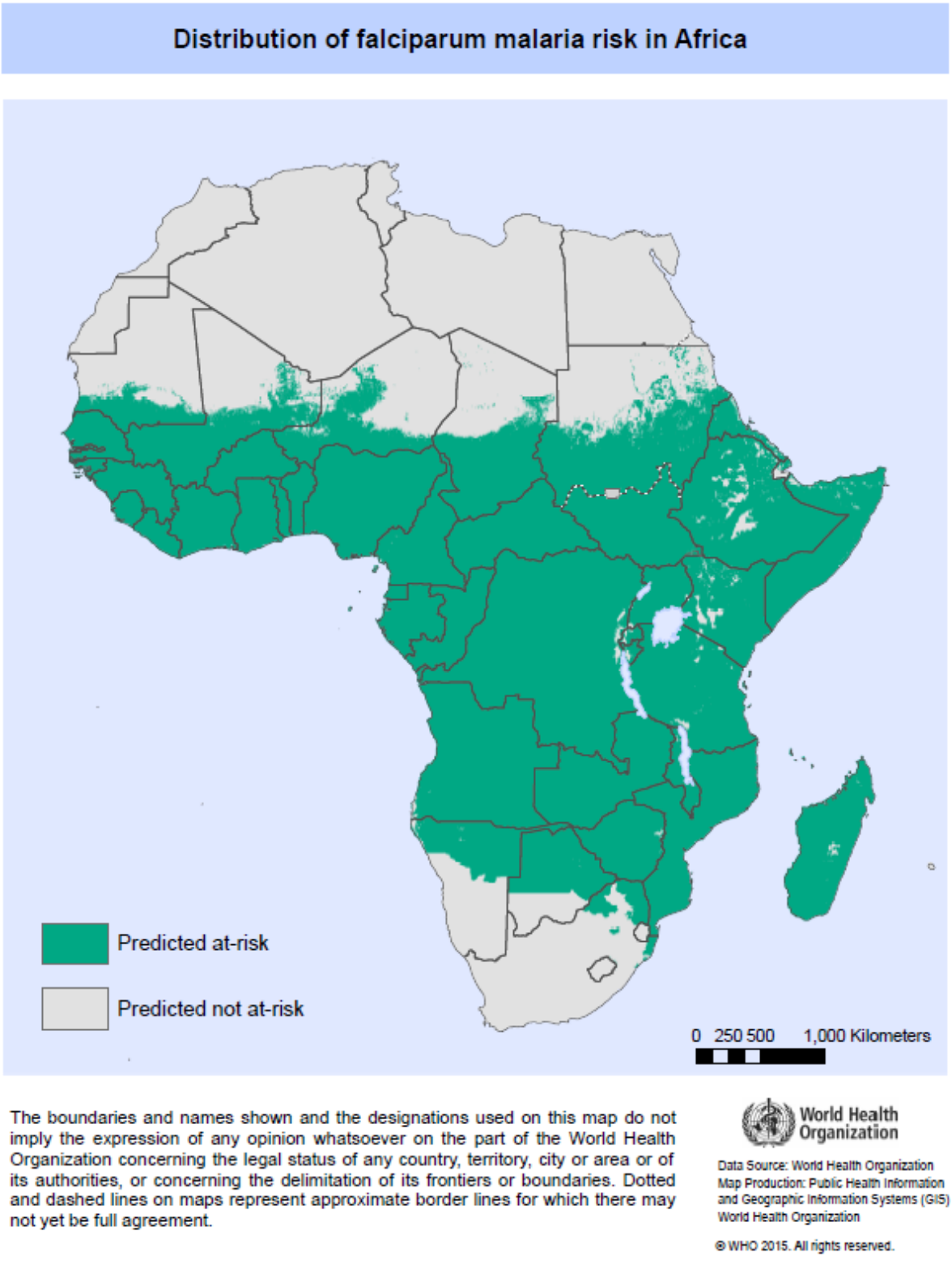



**Figure 3.2: Distribution of *Plasmodium falciparum* malaria infection risk in Africa.**
Areas at risk (coloured green) are those predicted in 2010 to have had an annual parasite incidence rate of at least 1 per 10,000 individuals – classified as stable transmission [13].

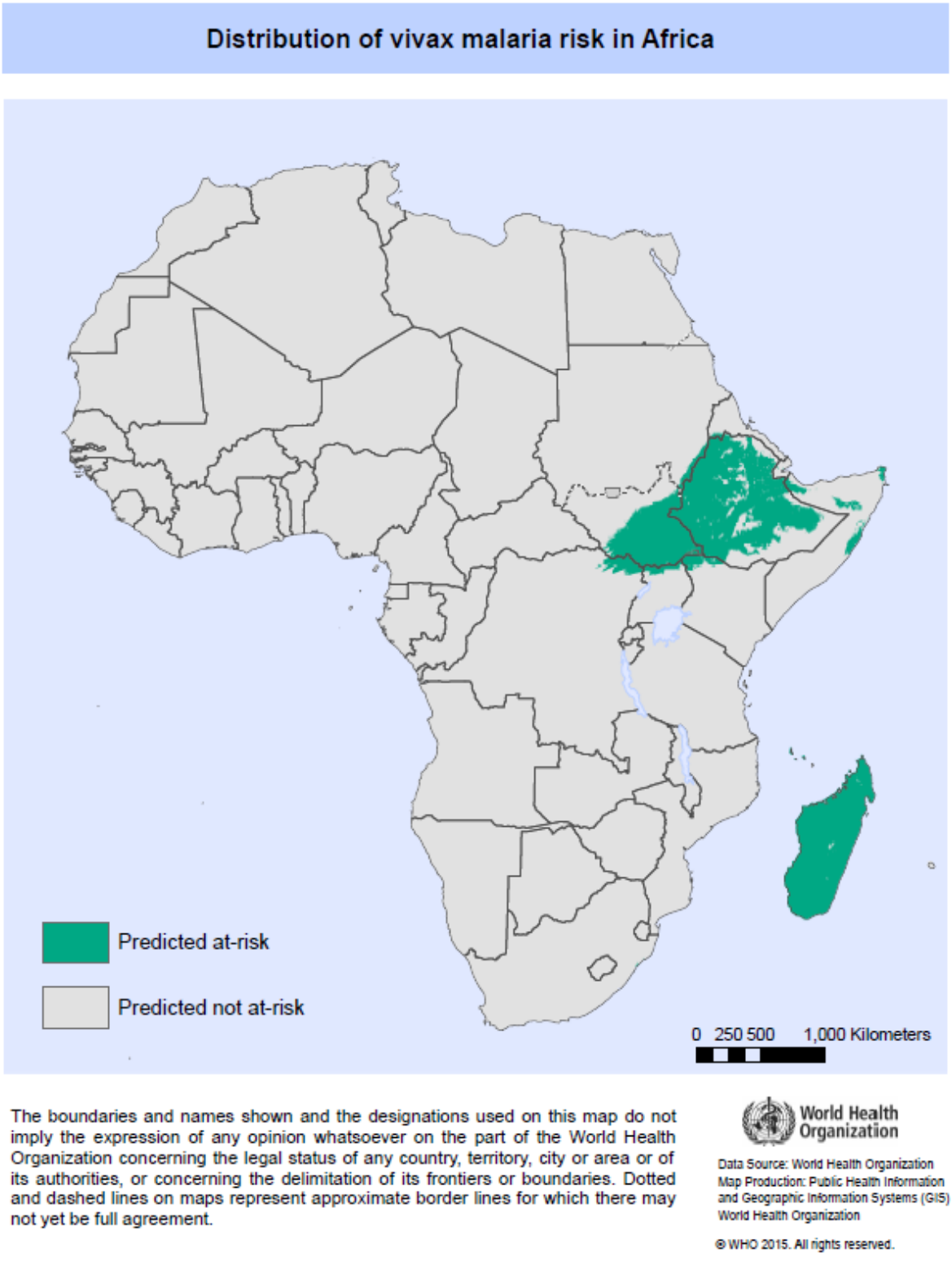



**Figure 3.3: Distribution of *Plasmodium vivax* malaria infection risk in Africa.**
Areas at risk (coloured green) are those predicted in 2010 to have had an annual parasite incidence rate of at least 1 per 10,000 individuals – classified as stable transmission [16].

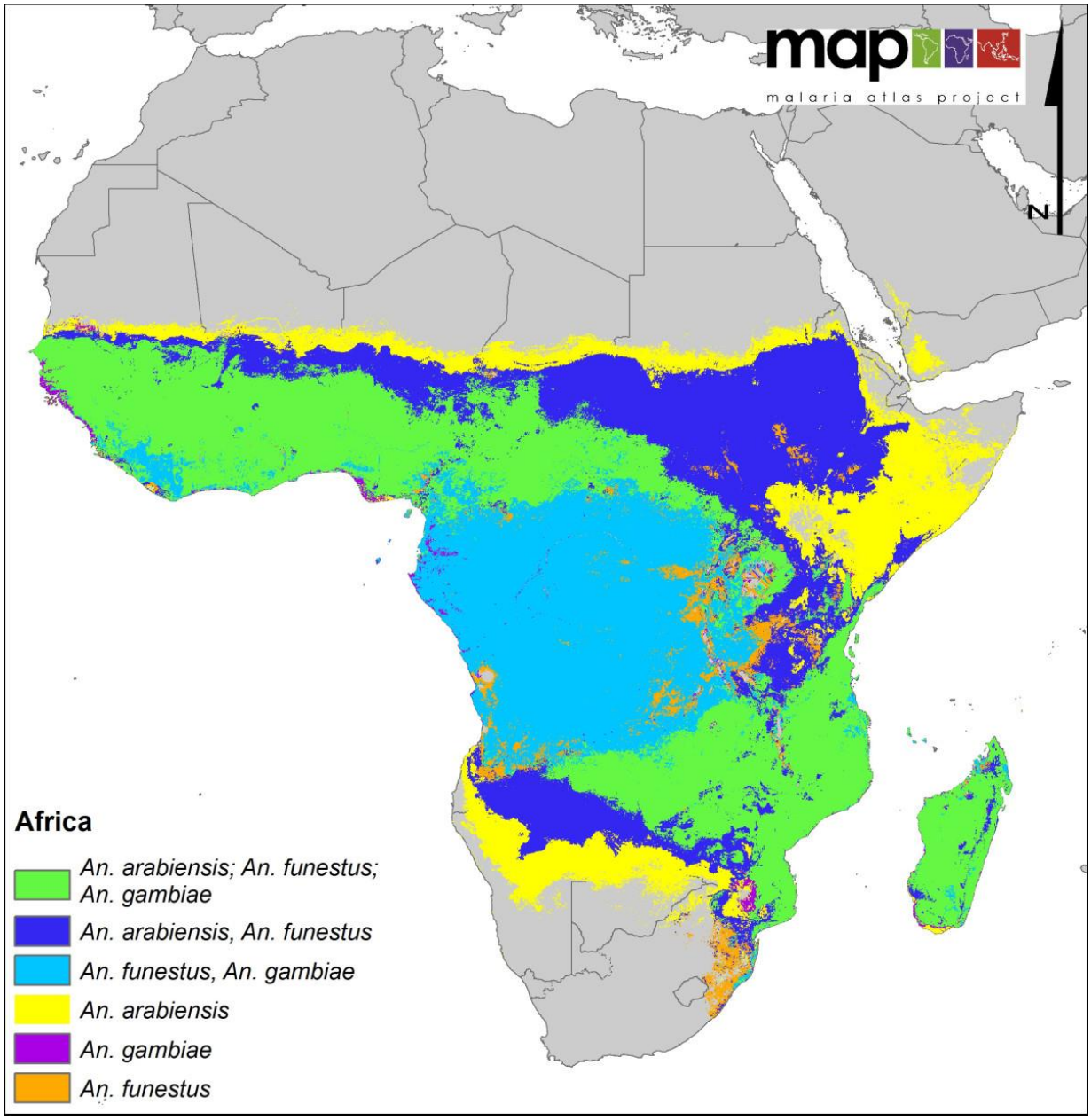



**Figure 3.4: The distribution of dominant *Anopheles* vectors of malaria in Africa.**
The coloured regions indicated which species are considered the most important for malaria transmission in that area. The distribution of these species was estimated using mosquito occurrence data collected between 1985 and 2009. Available at: http://www.map.ox.ac.uk/browse-resources/multiple-vectors/dominant_malaria_vectors/africa-plus/. Adapted from [17].

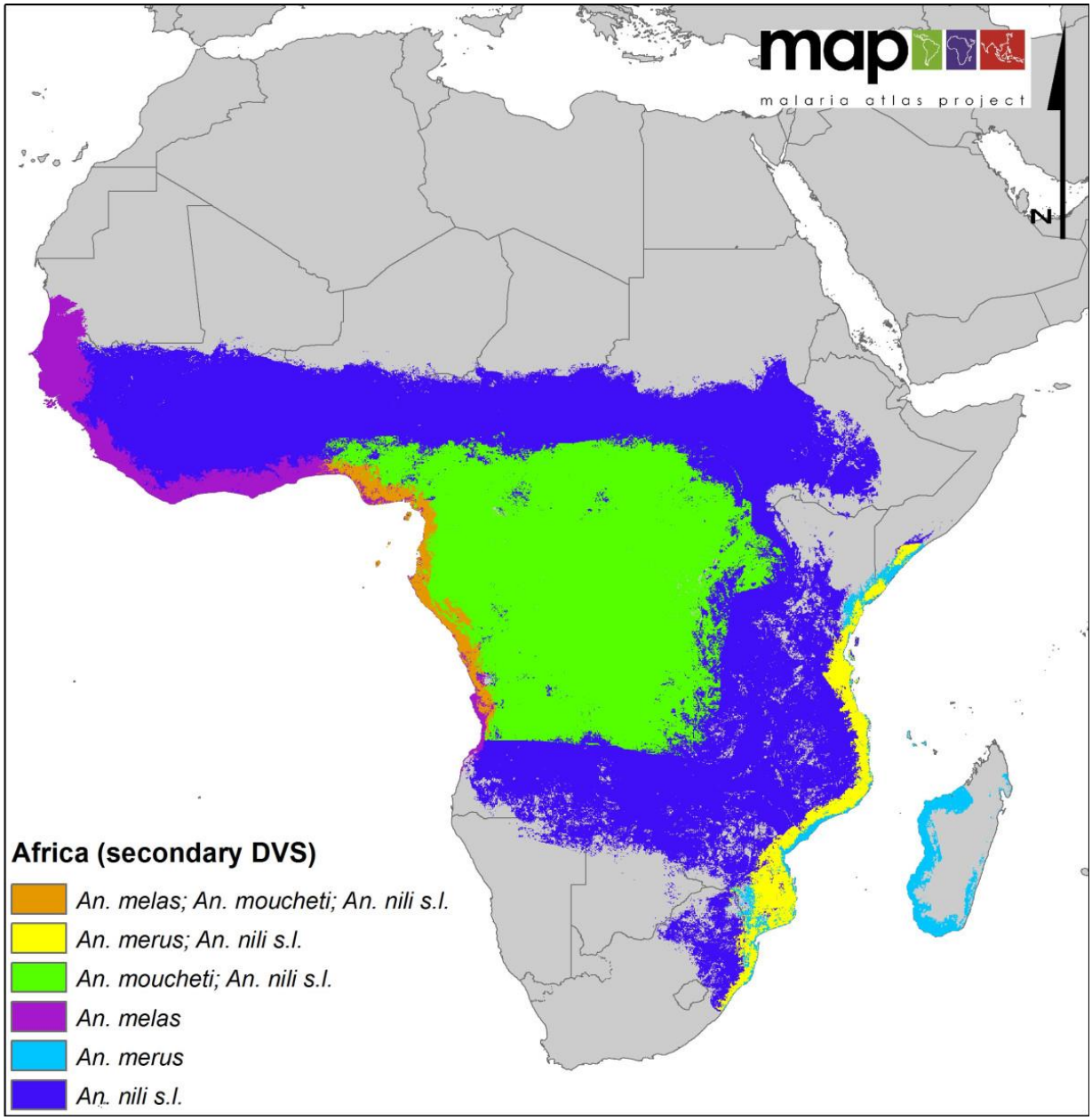



**Figure 3.5: The distribution of secondary *Anopheles* vectors of malaria in Africa.**
The coloured regions indicated which species are considered to play a less important role in malaria transmission in that area. The distribution of these species was estimated using mosquito occurrence data collected between 1985 and 2009. Available at: http://www.map.ox.ac.uk/browse-resources/multiple-vectors/dominant_malaria_vectors/africa-plus/. Adapted from [17].

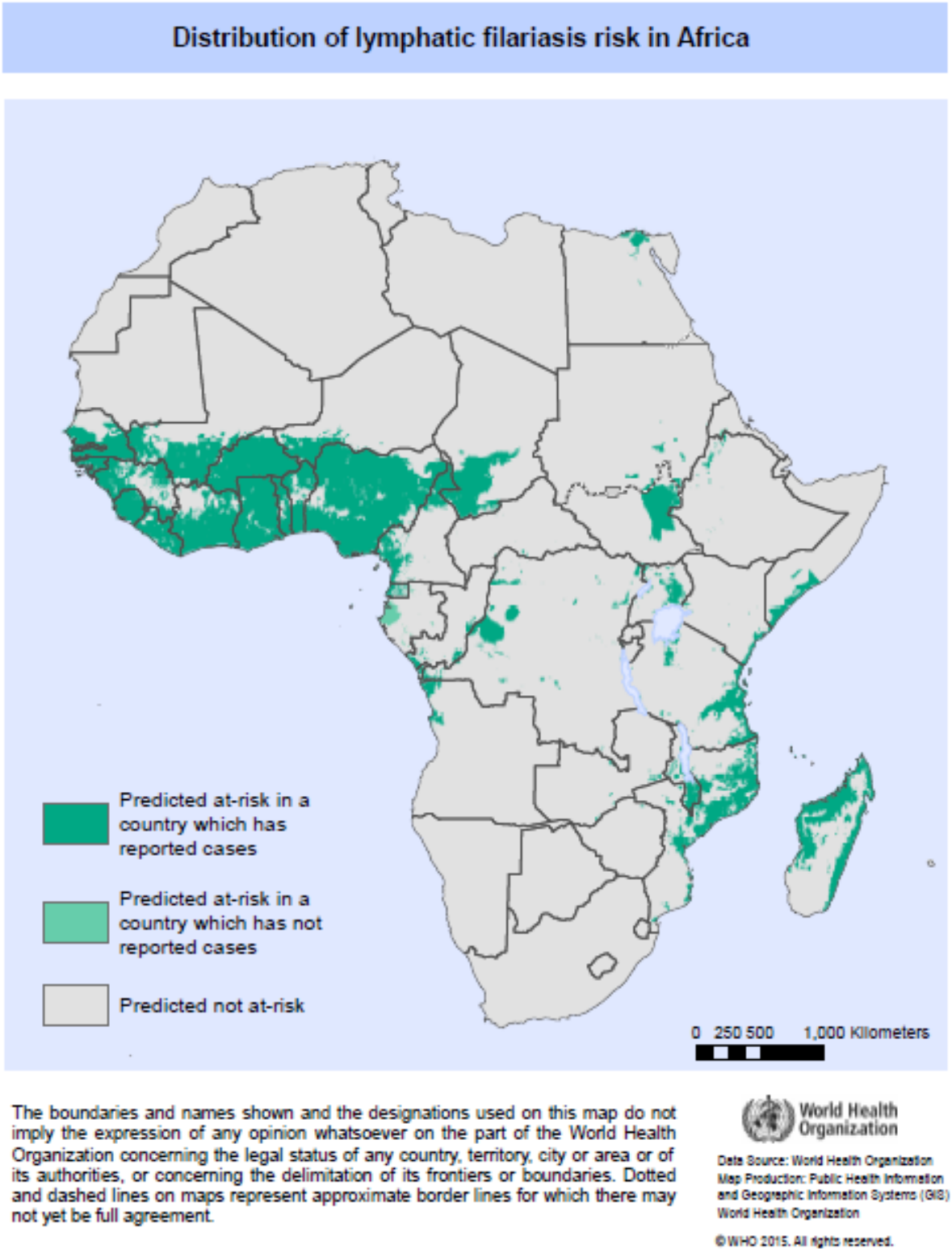



**Figure 3.6: Distribution of lymphatic filariasis infection risk in Africa**.
Areas at risk (coloured green) are those predicted to be environmentally suitable for the disease by [18]. Areas in light green are predicted to be suitable, but lie in countries which are not considered endemic for the disease and for which no occurrence records were recorded by [18].

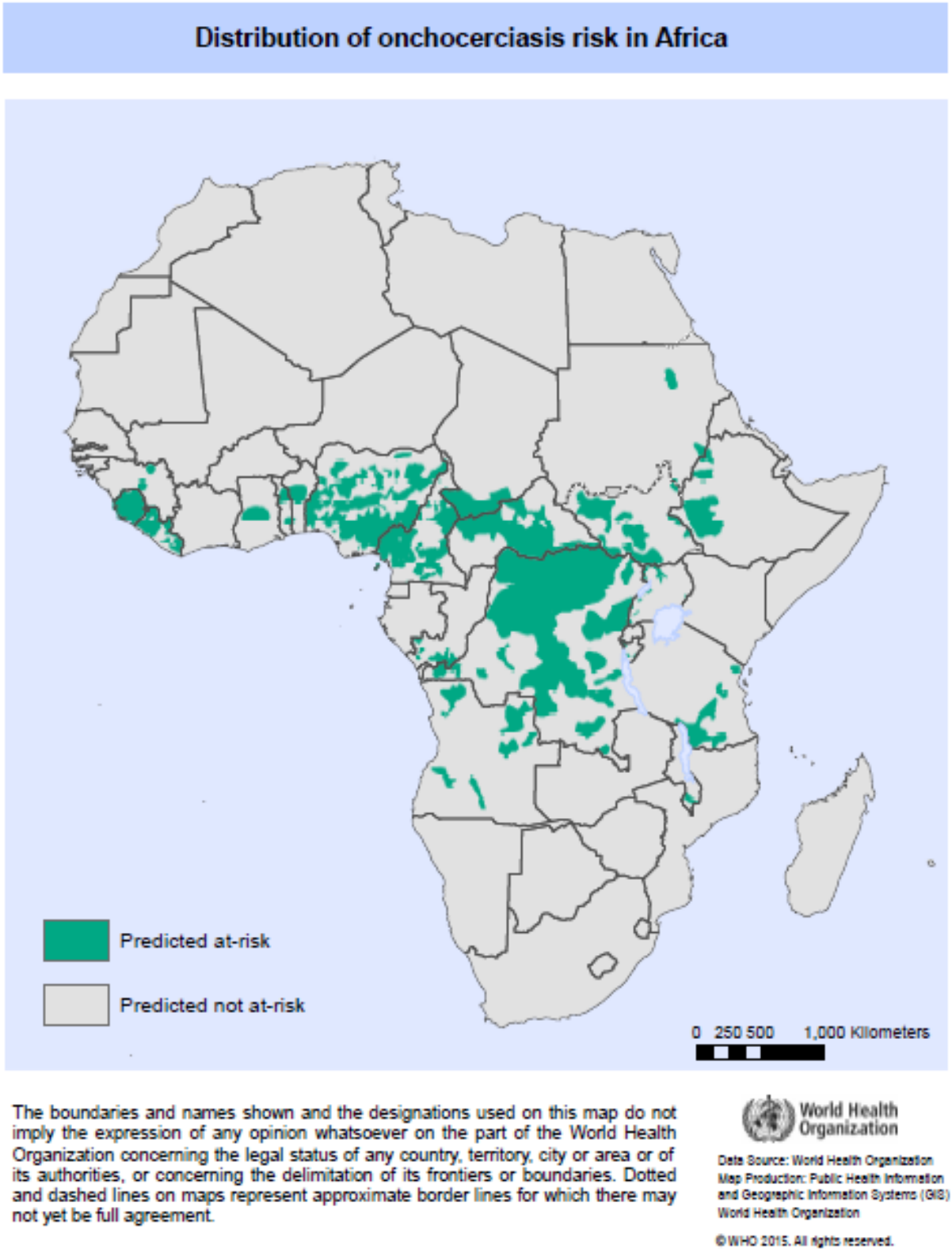



**Figure 3.7: Distribution of onchocerciasis infection risk in Africa**.
Areas at risk (coloured green) are those where control is deemed by the African Programme for Onchocerciasis Control (APOC) carried out between 2006 and 2013, or (in West Africa) regions of ongoing transmission identified at the end of the Onochocerciasis Control Programme (OCP) in 2002 [19-21].

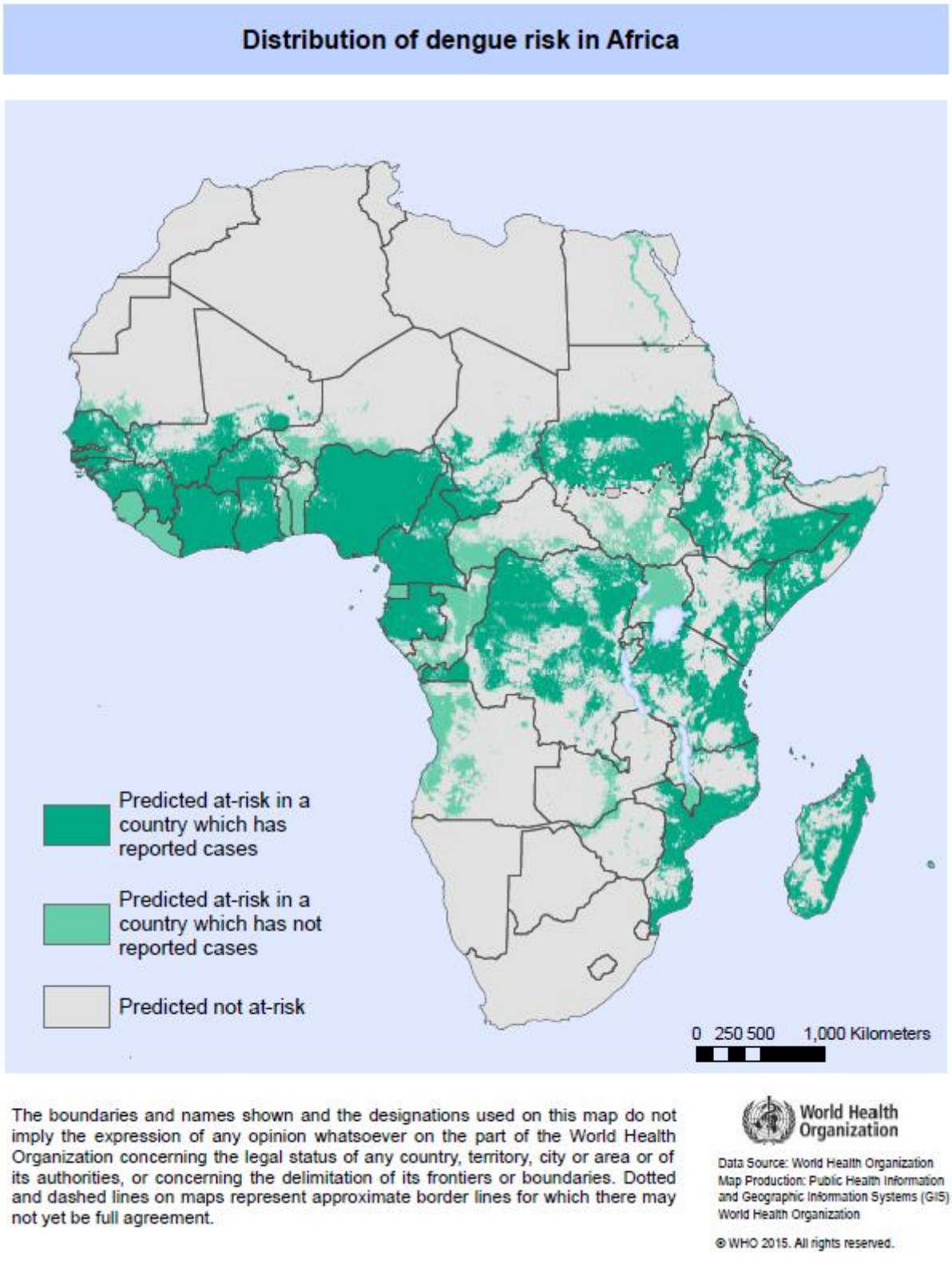



**Figure 3.8: Distribution of dengue infection risk in Africa.**
Areas at risk (coloured green) are those predicted to be environmentally suitable for the disease by [22]. Areas in light green are predicted to be suitable, but lie in countries which are not considered endemic for the disease and for which no occurrence records were recorded by [23].

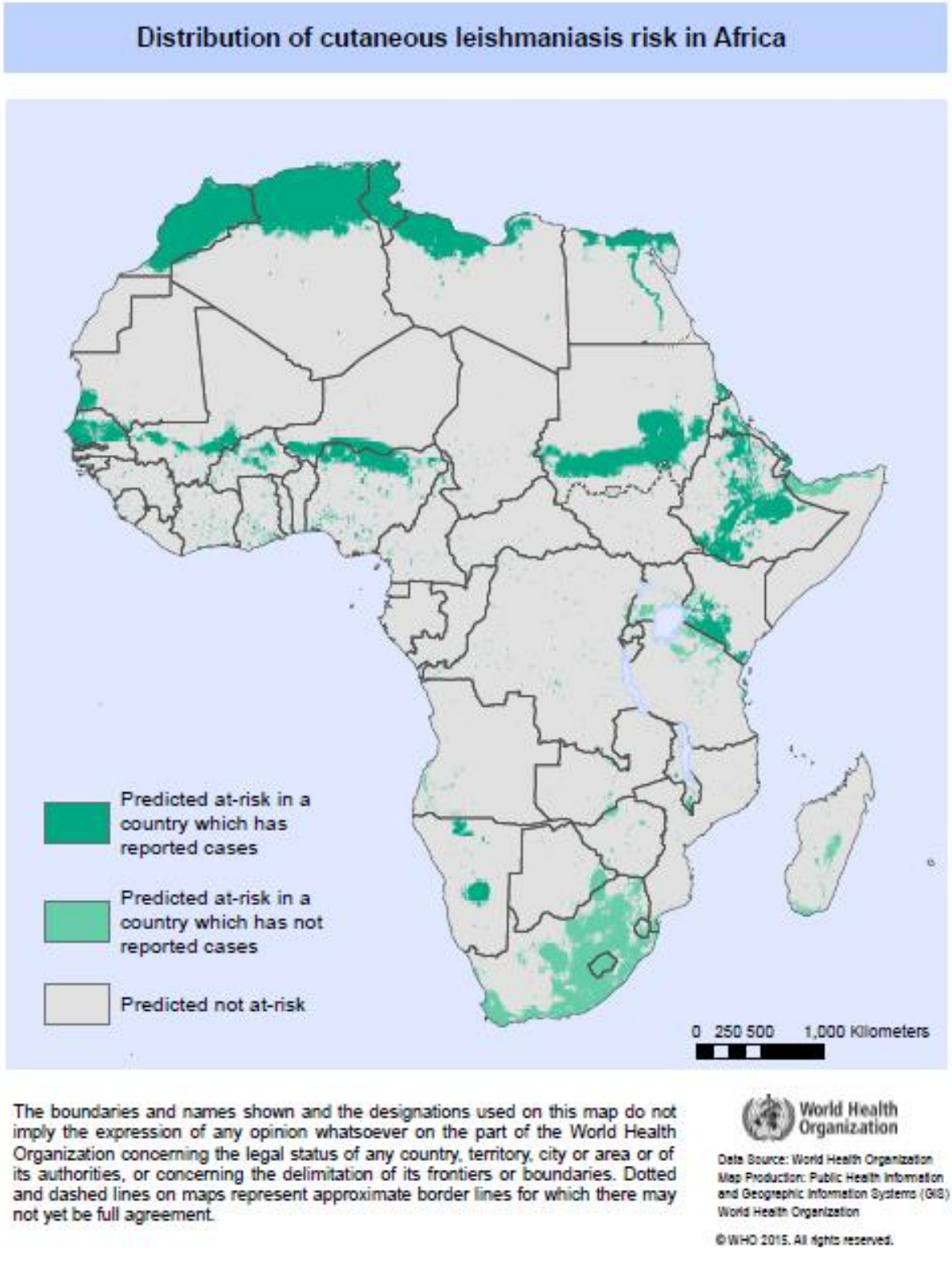



**Figure 3.9: Distribution of cutaneous leishmaniasis infection risk in Africa.** Areas at risk (coloured green) are those predicted to be environmentally suitable for the disease by [24]. Areas in light green are predicted to be suitable, but lie in countries which are not considered endemic for the disease and for which no occurrence records were recorded by [24].

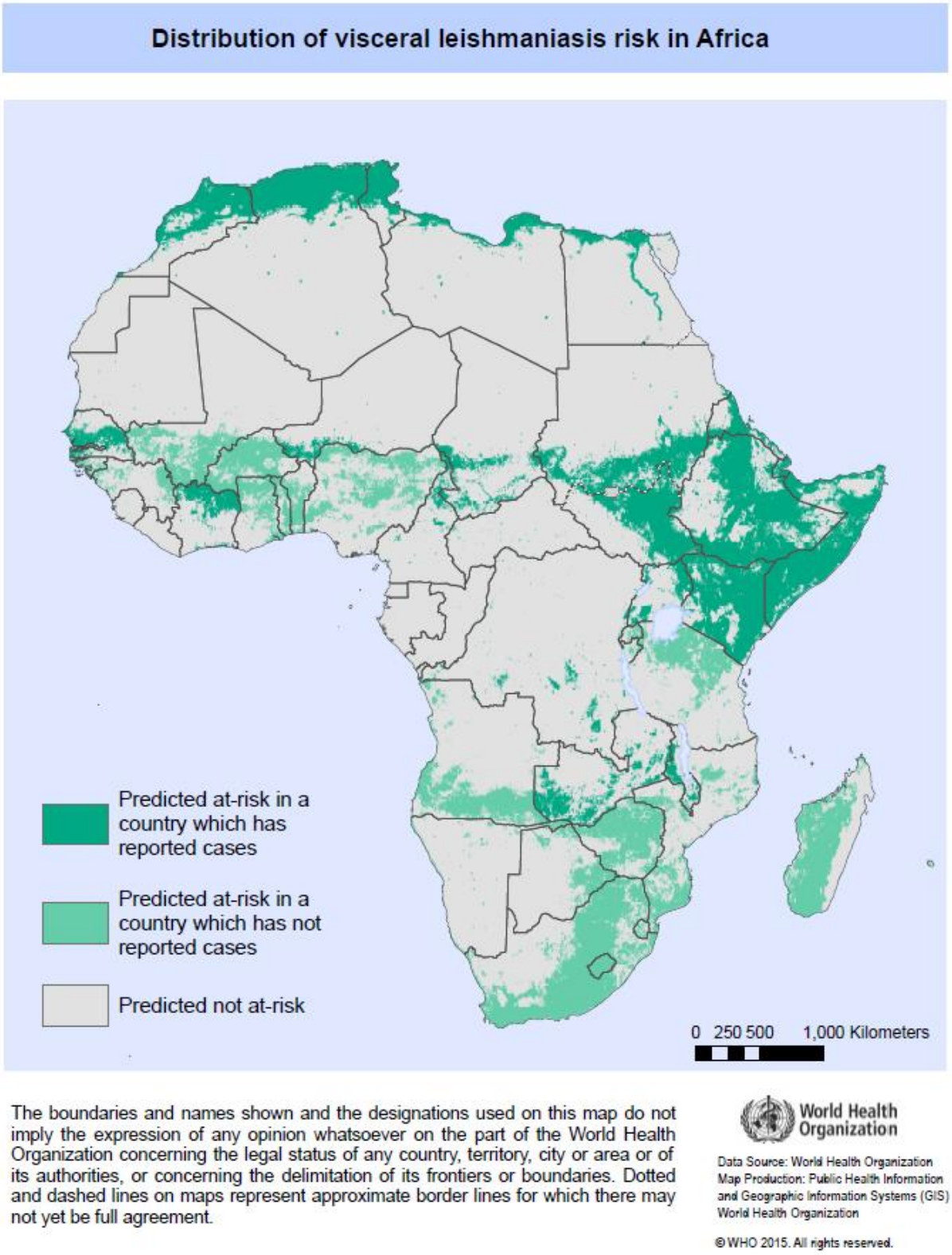



**Figure 3.10: Distribution of visceral leishmaniasis infection risk in Africa.**
Areas at risk (coloured green) are those predicted to be environmentally suitable for the disease by [24]. Areas in light green are predicted to be suitable, but lie in countries which are not considered endemic for the disease and for which no occurrence records were recorded by [24].

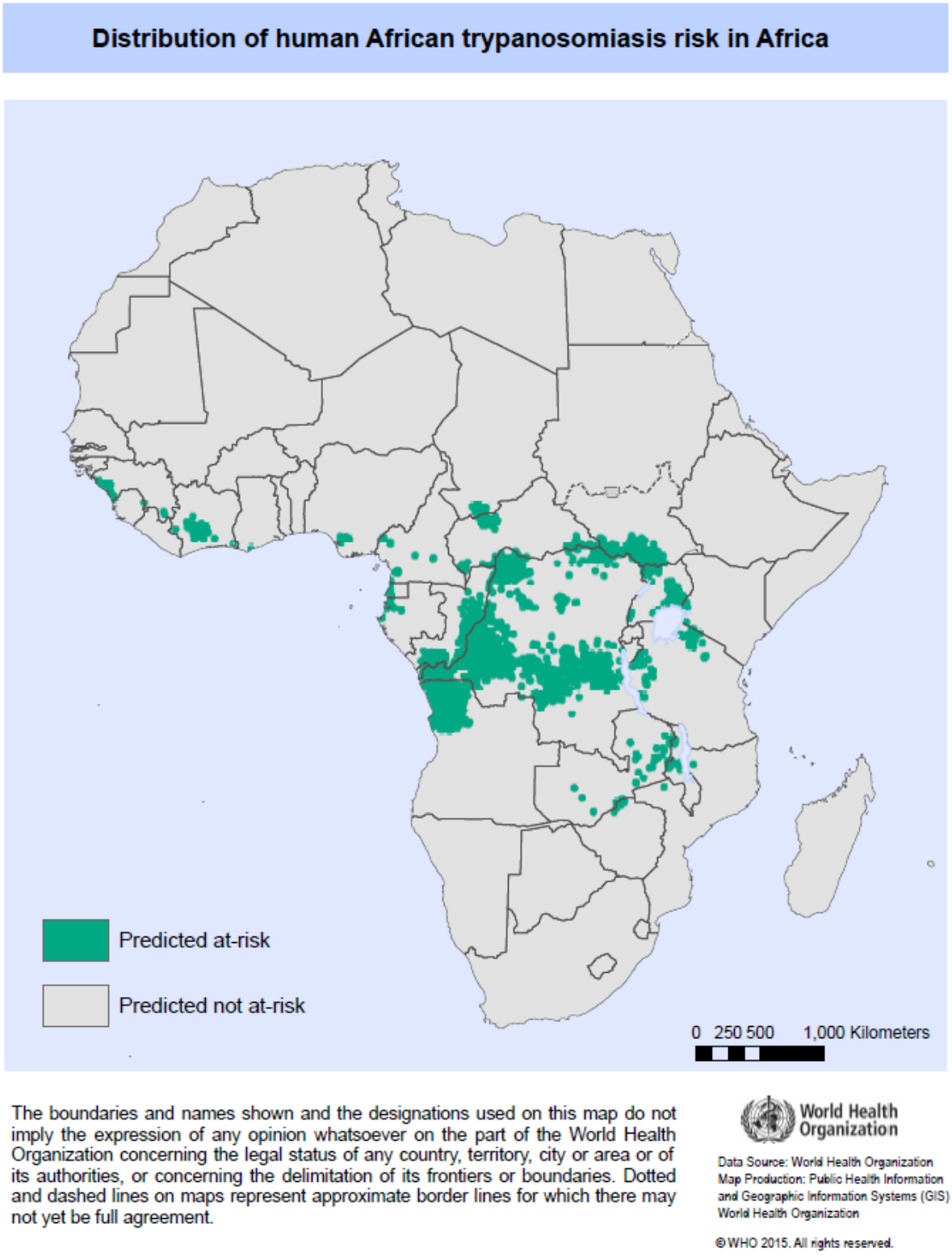



**Figure 3.11: Distribution of human African trypanosomiasis infection risk in Africa**.
Areas at risk (coloured green) are those close to known cases from 2000-2009 [25].

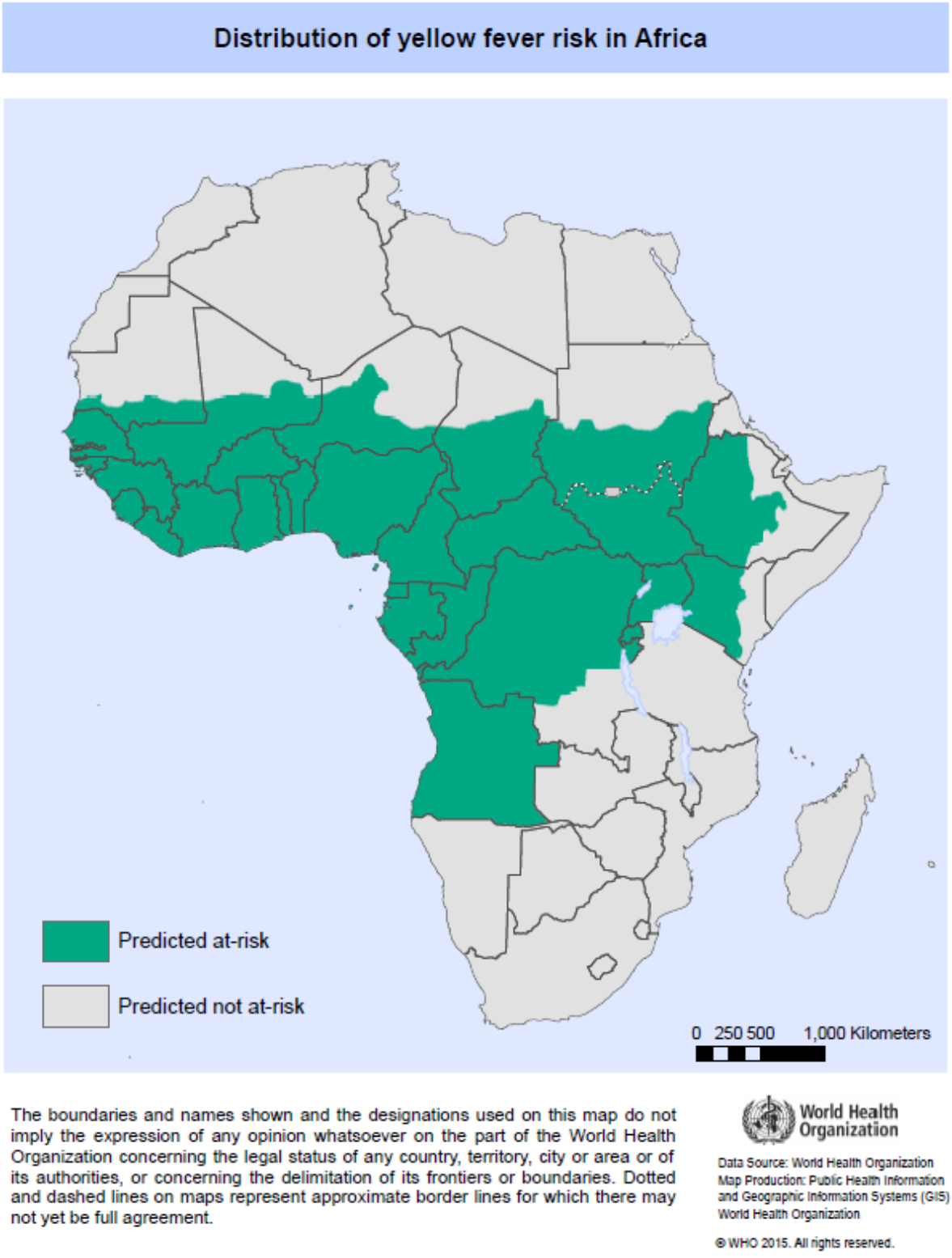
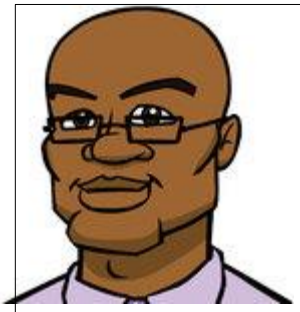



**Figure 3.12: Distribution of yellow fever infection risk in Africa.**
Areas at risk (coloured green) are those considered to be endemic for the disease in 2011 by [26].



**KEY POINT**

While maps can be a good guide to infection/disease risk, they are not foolproof! Always check country epidemiological data. If the maps identify gaps or highlight the potential for pathogen transmission in areas where you have not looked previously, then this might suggest the need for local surveys and data collection.

### 3.2.2 Step 2: Investigate epidemiological data (first administrative level)

Our maps provide a rough guide to where populations are at risk from infection with vector-borne pathogens at national and first administrative level. These maps are a guide only and have several limitations. Firstly, these maps show areas where populations are at risk from infection, rather than giving an indication of how high the incidence or prevalence of disease/infection is which is a more epidemiologically relevant parameter (although these maps are available for malaria [13]). Secondly, infection risk is not static over time and may vary over the year and between years. Thirdly, infection risk will vary between populations within geographic areas. It is important for programme managers to consider whether the distribution of risk shown in the maps seems a realistic representation of their local situation. Do the maps highlight gaps in your understanding of disease distributions? Gaps in your understanding of risk should be investigated further using surveys or data collection. In the absence of local data, we suggest that these maps be used to identify at first administrative level (regional level), diseases which could be targeted by integrated vector management (IVM). However, additional epidemiological data are likely to be available in-country and should be consulted where possible.

Epidemiological data can come from public or private health facilities via in-country health management information systems, community surveys or external sources (Table 3.1). These data, where available, could be used instead of or in tandem with the disease distribution maps included in this Toolkit. Knowledge of the prevalence or incidence of an infection or disease will allow resources to be targeted efficiently to most at risk populations.

**Table 3.1: Sources of epidemiological data on VBD**

| Source | Disease(s) covered | Resource |
|---|---|---|
| Health management information system | All endemic diseases | Country / programme data |
| Community surveys | Differs | |
| Rapid epidemiological assessment / mapping | Onchocerciasis | |
| Multiple indicator cluster surveys (MICS) | Malaria | http://www.childinfo.org/mics.html<br>http://www.micscompiler.org/ |
| Demographic and health surveys (DHS) | Malaria | http://www.dhsprogram.com/ |
| Malaria indicator survey (MIS) | Malaria | http://www.dhsprogram.com/<br>www.malariasurveys.org |
| Malaria Atlas Project | Malaria | http://www.map.ox.ac.uk/ |

| | | |
|---|---|---|
| Global Atlas of Helminth Infections | Lymphatic filariasis and schistosomiasis | http://www.thiswormyworld.org/ |
| Global Neglected Tropical Diseases Database | Lymphatic filariasis and leishmaniasis | http://www.gntd.org |
| Non-governmental organisations (NGOs) | Sightsavers, Helen Keller International and Carter Center (trachoma and onchocerciasis), Mèdecins sans Frontierès etc. | http://www.sightsavers.org/<br>www.hki.org<br>http://www.cartercenter.org<br>http://www.msf.org/ |

### 3.2.3 Step 3: Assess vector distribution and ecology

As well as knowing where there is a risk of infection with a particular vector-borne pathogen, assessment of vector distributions is essential for IVM. This is so that we can tailor the control programme to the individual vectors, which have different biology, ecology and behaviour and so may require the use of different vector control methods.

Whilst our maps of disease risk show areas where suitable vector species are present for each disease, they do not identify which vector species are most important in each area. There are excellent published data on geographic distributions of dominant *Anopheles* vectors of malaria (Figure 3.4 and 3.5) but less information is available for other disease vectors. Sources of more information are outlined in Table 3.2. There is currently, little information on the geographic distribution of snails as intermediate hosts of schistosomiasis or flies as vectors of *Chlamydia trachomatis* given their ubiquity.

**Table 3.2: Sources of information on geographic distributions of disease vectors**

| Disease | Source of information on vector distribution |
|---|---|
| Malaria and O'nyong-nyong virus | Figure 3.4 and 3.5<br>More detailed information on the ecology and bionomics (e.g. larval site characteristics, adult feeding and resting) of these species can be found in the paper: Sinka *et al* (2010) The dominant *Anopheles* vectors of human malaria in Africa, Europe and the Middle East: occurrence data, distribution maps and bionomic précis [10]. |
| Lymphatic filariasis | See Figure 3.4 and 4.5 for *Anopheles* vectors shared with malaria.<br>Annex 1 lists primary and secondary vectors by large geographic region: in WHO (2013). Lymphatic filariasis: a handbook of practical entomology for national lymphatic filariasis elimination programmes. [27] |
| Dengue, yellow fever, Rift Valley fever and chikungunya | Maps of the global distributions of the dengue vector mosquitoes *Aedes aegypti* (which also transmits yellow fever and chikungunya) and *Ae. albopictus* are given in [28], although these national level maps provide little spatial precision. |
| Leishmaniasis | A list of the dominant sandfly vectors of leishmaniasis in each endemic country can be found in [29]. Information on the main transmission cycles of the leishmaniases, the regions in which they occur and the vector species responsible is given in [30]. |
| Human African trypanosomiasis | Programme Against African Trypanosomiasis [31]<br>http://www.fao.org/ag/againfo/programmes/en/paat/maps.html |

| | |
|---|---|
| Onchocerciasis | Very little information is available on the dominant blackfly vectors |

In addition to published maps, programmes may have their own data on vectors collected through existing surveillance schemes. Therefore, it is a good idea to check VBD control programme reports, as well as information collected by other entities such as veterinary services, ministry of agriculture, and non-governmental organisations (NGOs).

If information on vector distributions is patchy, it may be beneficial to identify which ecosystems are present in your country, since this can give an indication of which vectors and diseases can be expected. There are six main ecosystems (village, urban, riceland, river and estuary ecosystems, small-scale farming systems and plantations) which are outlined in Box 3.1 [32]. In most instances, a combination of ecosystems will be found, for example, in villages near rural settings, or where riverine systems adjoin small-scale farming. Determining the ecosystem type in an area is not a shortcut to determining control interventions but can be a useful process to think through the disease risks and opportunities for control [33].

Vector distributions and ecosystems also give an indication of which types of VBD may emerge over time in your setting or have the potential for re-introduction if they have been eliminated. Maps provided in this Toolkit which predict risk using environmental suitability (leishmaniasis, dengue and LF) will also indicate areas where reintroduction of a disease is a risk.

**Box 3.1: Ecosystem basis for assessing vector borne disease risk (adapted from [30])**

**Village ecosystems (Major: malaria, lymphatic filariasis, Minor: leishmaniasis, human African trypanosomiasis):**

Village agro-ecosystems are defined as human settlements comprising of 10 or more households that form an agriculture-based economic and social entity which provides certain facilities (e.g. school, health centre, farming co-operative) that benefit the community. In this environment human settlement for the production of food creates numerous opportunities for disease vectors to thrive – primarily *Anopheles* spp. (malaria and lymphatic filariasis vectors).

Corn crop, Ghana (UN Photo)

Climatic conditions in sub-Saharan Africa (SSA) are suitable for vectors at nearly all times of the year, although temperature in highland areas and rain may be limiting factors.

**Urban ecosystems (Major: malaria, lymphatic filariasis, dengue, chikungunya):**

SSA is experiencing rapid urbanisation. Rapid urban growth is often accompanied by poor housing, overcrowding, pollution, no waste collection, lack of hygiene and sanitation, difficult access to water, unprotected water reservoirs, weak services, low productivity, and widespread economic disparity. Urbanisation leads to changes in vector ecology and can present new risks for VBD. For example, inappropriately designed latrines and open drains provide breeding sites for *Culex quinquefasciatus*, the lymphatic filariasis vector. Market gardens for growing fruits and vegetables and shallow drains provide breeding sites for malaria vectors of the *Anopheles* spp. Water storage tanks and other containers provide breeding habitats for the dengue vector *Aedes aegypti*.

**Riceland ecosystems (Major: malaria, Minor: lymphatic filariasis, dengue):**

Rice growing areas are found in the floodplains of seasonal rivers, natural wetland areas and man-made irrigation systems (e.g. Office du Niger, Mali; Vallée du Kou, Burkina Faso, Benue river system, Cameroon and Mwea irrigation system, Kenya). The expansion of rice growing into these areas had created breeding habitats for malaria vectors (*Anopheles gambiae s.l., An. funestus* and *An. arabiensis*).

Rice plants being removed for transplanting in fields near Tananarive, Madagascar (UN Photo)

**River and estuary ecosystems (Major: malaria, onchocerciasis, African trypanosomiasis, Minor: leishmaniasis, west Nile virus, Rift Valley fever, lymphatic filariasis):**

Small, fast flowing streams are breeding sites for blackflies (*Simulium* spp.) that lay their eggs on plants hanging or growing in running water.

Several species of riverine tsetse flies are strongly associated with riverine and lacustrine (lake) systems which provide the relatively high humidity required by adults and pupae. Adult flies find blood meals on animals and humans living in or entering the riverine or lacustrine habitats.

Crops growing on flood plain of River Niger, Bamako, Mali (A. Wilson)

Where rivers flow into the sea, mangrove forests provide shelter and breeding sites for vectors adapted to brackish water conditions. For example, the saltwater mosquitoes *Anopheles melas* (West Africa) and *An. merus* (East Africa) can be locally important malaria vectors. The flood plains of large river such as the River Nile, Zambezi River, Congo River and Niger River) are used for cultivation of crops including rice, resulting in proliferation of malaria vectors.

**Small-scale farming systems (Major: malaria, lymphatic filariasis, Minor: human African trypanosomiasis):**

Small-scale farming systems are defined as less than 10 households that engage in farming activities, chiefly subsistence farming, as the chief economic activity and that do not provide communal services. Poor education and lack of income prevent the improvement of living conditions (such as a better constructed house or installation of a water tap) and preventive measures are not used. Communities are often remote and have difficult access to health facilities. Subsistence farming is strongly associated with poverty and VBD, particularly malaria and lymphatic filariasis. Pastoral and village cattle may be reservoirs of African trypanosomiasis, particularly in East Africa.

**Plantations (Major: human African trypanosomiasis, malaria):**

Commercial (plantation) agriculture often causes dramatic shifts in the environment, often replacing tropical rainforest with tea, coffee, oil palm, sisal, cocoa or cotton. Many vectors have been able to adjust and adapt to these man-made environments, including the malaria vector *Anopheles* spp. that breed in drainage channels, pools and puddles and tsetse flies (*Glossina* spp.) which find sufficient shade and blood meals from mammals within the plantations for survival and efficient transmission of the disease.

Tea plantation, Mbeya, Tanzania (UN Photo)

**KEY POINT**

Urban ecosystems can present new habitats for vectors and drive VBD. Therefore, it is a good idea to assess population density in your country and identify rural and urban areas. If you do not have this information to hand you can access population maps from websites such as Global Urban-Rural Mapping Project (GRUMP, v1) (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3)

### 3.2.4 Step 4: Stratify areas according to diseases present and their current incidence

Once you have assessed the disease situation in steps 1-3, programme managers should be in a position to stratify (classify) disease endemic areas according to their epidemiological and ecological characteristics. Hence, stratification is used to identify areas in which different approaches to disease control are indicated. When a country is co-endemic for multiple VBDs, stratification becomes more complicated.

This is usually done at first administrative level (region), since this is the level at which VBD programmes are usually organised. Stratification of areas should be a collaborative process involving programme staff from the regions and other stakeholders, such as NGOs. It is important to use the most current data available on disease incidence and the vector. Stratification should be revisited regularly to take into account changing disease and vector patterns.

Box 3.2 gives a worked example of the stratification process for VBD in Tanzania.

**Box 3.2: An example of stratification by diseases present and their incidence in Tanzania**

The steps required in stratification are outlined below:

***Step 1: Assess maps and list diseases present by first administrative level (region).***

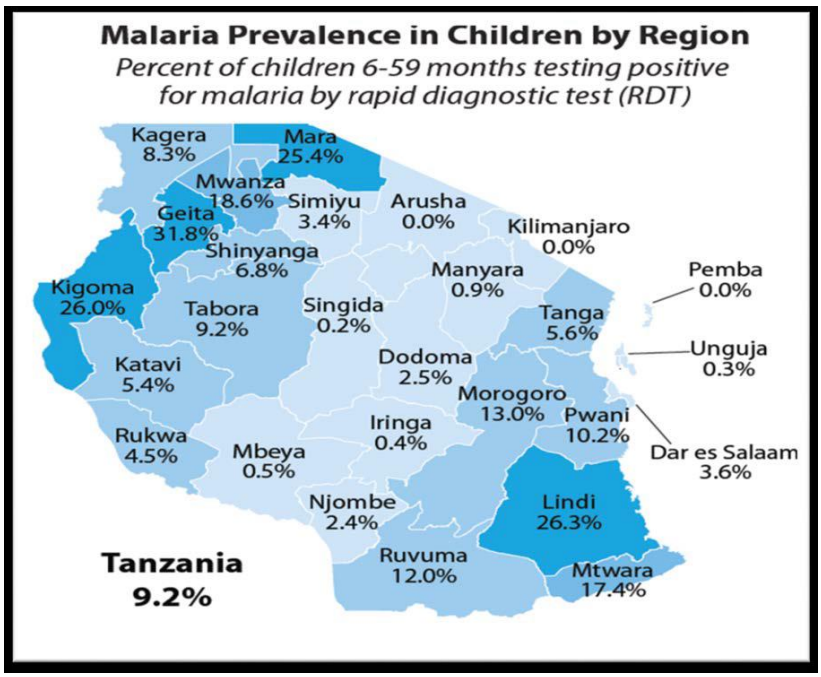
Maps indicating risk of infection or disease endemicity risk maps for Tanzania are shown. Dengue fever, human African trypanosomiasis, *P. falciparum* malaria, onchocerciasis, lymphatic filariasis, schistosomiasis and trachoma (www.trachomaatlas.org) were found to be endemic. There are areas of Tanzania that are predicted to be suitable for transmission of leishmaniasis, but no occurrence records were found and Tanzania is not considered endemic for this disease. Maps do not indicate that yellow fever or *P. vivax* malaria is endemic in Tanzania.

| Region | Disease | | | | | | |
|---|---|---|---|---|---|---|---|
| | Dengue | HAT | Onchocerciasis | Falciparum malaria | Lymphatic filariasis | Schistosomiasis | Trachoma |
| Tabora | x | x | x | x | x | | |
| Rukwa | x | x | - | x | x | | |
| Morogoro | x | - | x | x | x | | |
| Lindi | x | - | - | x | x | | |
| Ruvuma | x | - | x | x | x | | |
| Mbeya | x | - | x | x | x | | |

Make sure you use only up-to-date data on diseases present or infection risk since the disease situation is likely to change over time and new VBD may appear.

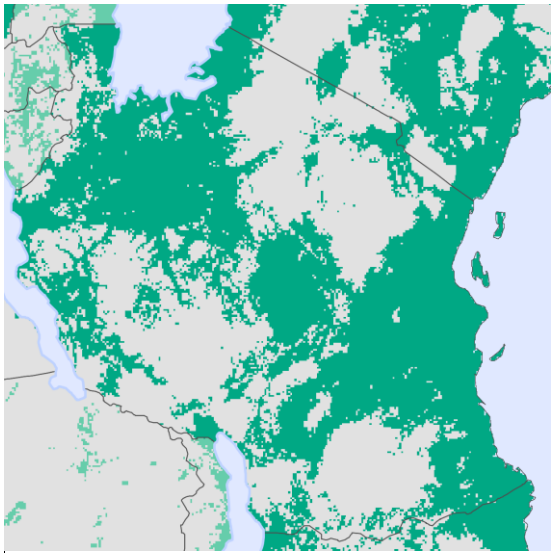
***Step 2: Investigate epidemiological data at first administrative level***

Possible sources of epidemiological data include country data as well as external sources such as the Malaria Atlas Project maps for malaria. The disease with the highest burden should guide the IVM programme at the first administrative level. Of all the VBD present in Tanzania, malaria has the highest burden. Determine which areas have the highest incidence / prevalence of malaria and categorise them from highest to lowest for prioritisation of intervention. The figure shows malaria prevalence in under 5s in Tanzania from the HMIS survey (2011-12).

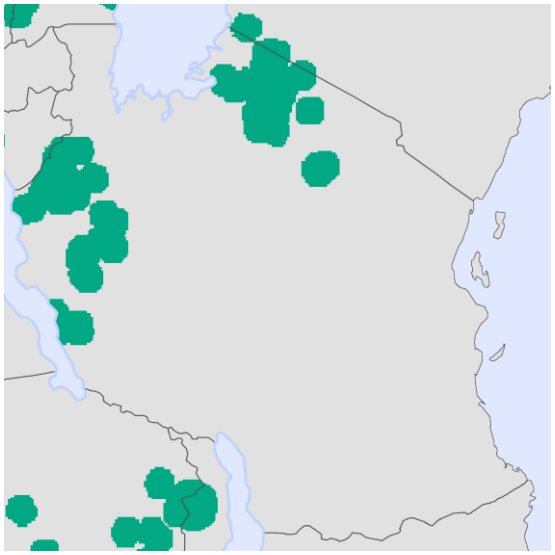





The same process of identifying high and low prevalence areas for prioritising intervention should be used

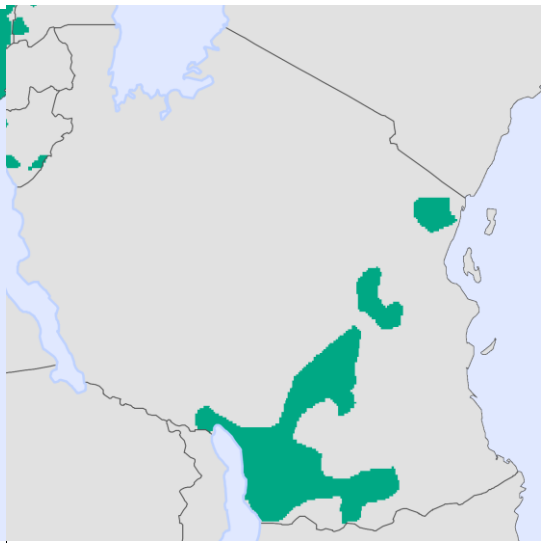


Dengue fever

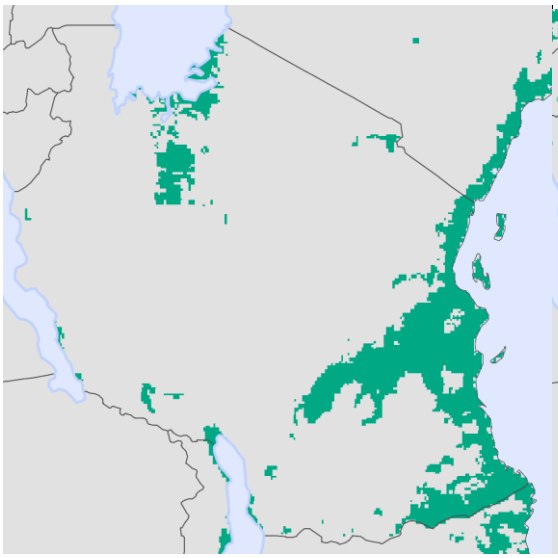


Human African trypanosomiasis

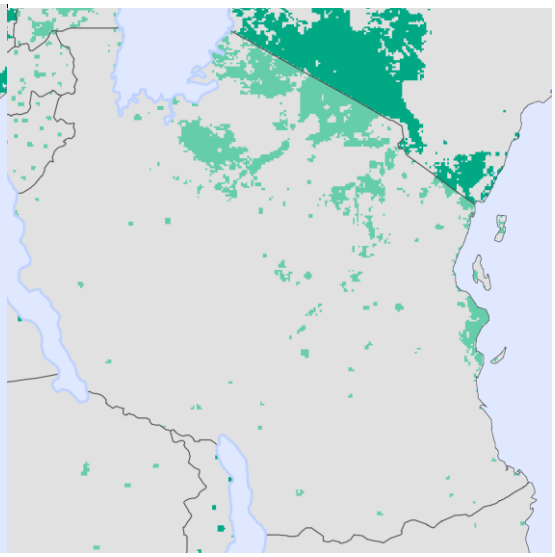
*P. falciparum* malaria



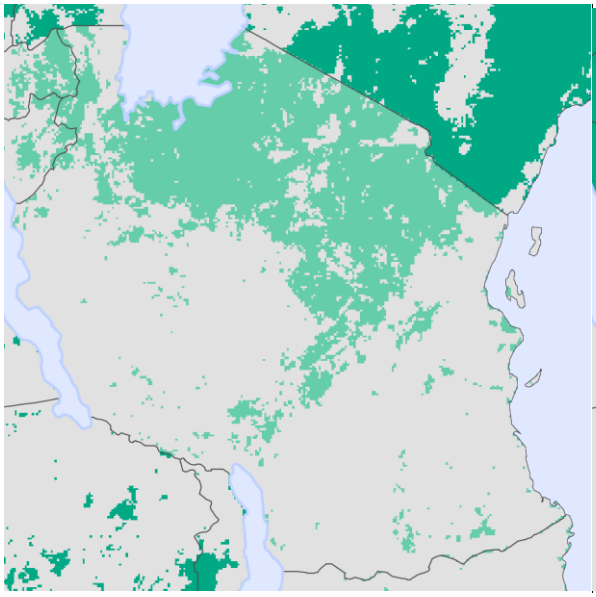
Onchocerciasis

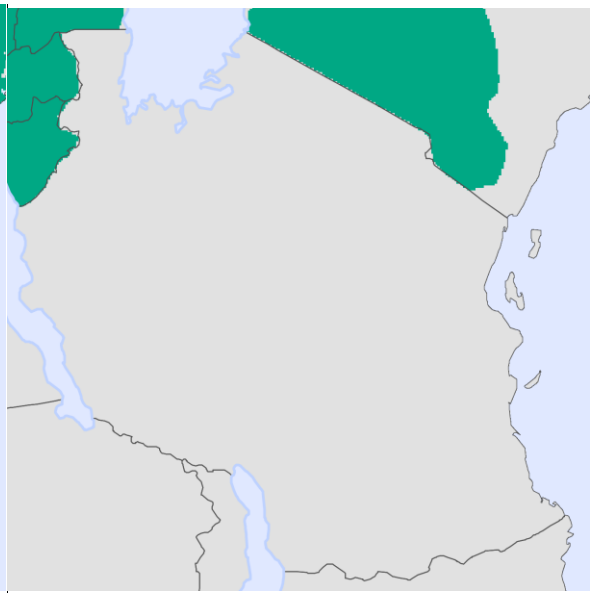


Lymphatic filariasis



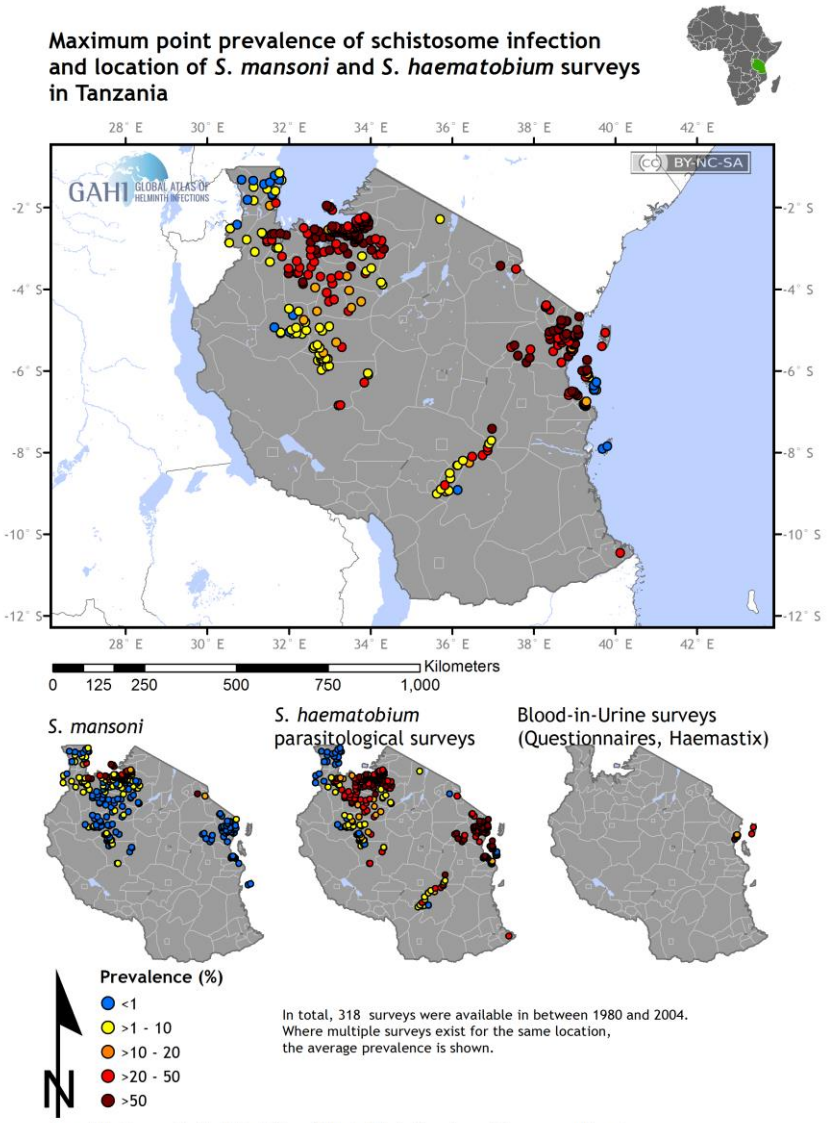
Cutaneous leishmaniasis





Visceral leishmaniasis

Yellow fever



***Step 3: Think about what determines disease ecology***

Think about where diseases are and how this relates to factors such as population density, socioeconomic conditions and the environment (e.g. elevation, land use, water bodies, potential animal reservoirs of infection). Many countries will already have thought about this to some extent, particularly with respect to eco-epidemiological types e.g. tropical Africa savannah, forest and forest fringes, highland and desert fringes (See Box 4.1).

In Tanzania dengue risk is clustered in more highly populated regions, while onchocerciasis occurs in mountainous regions near Iringa. Human African trypanosomiasis is correlated to some extent with large game parks and reserves.

***Step 4: Assess vector distribution***

Using published information or in-country data, identify which are the main disease vectors present.

***Step 5: Identify potential animal reservoirs***

Identify where large concentrations of cattle or wildlife are found.

***Step 6: Where evidence on disease endemicity is weak or patchy, additional surveys are recommended.***

For example, maps indicate the areas of Tanzania are environmentally suitable for leishmaniasis, although cases have not been reported from Tanzania. It may be that leishmaniasis is actually present in this area and therefore it would be advisable to conduct population based surveys to confirm the absence of this disease.

## 3.3 Local-level analysis (district level and below)

**CONSIDER: Are there differences in disease incidence within regions?**

**Are there other environmental and human factors which should be taken into account?**

While stratification at a regional level is useful in decision making and prioritising resources at a coarse scale, in many cases the main determinants of VBDs show heterogeneity at a much finer scale. For example, determinants may include concentrations of human habitation, at-risk groups such as hunters who are active throughout the night or a major vector breeding habitat such as an area of irrigated rice production. Determinants of disease therefore need to be identified and mapped at lower levels of administration (district and below). You can find more information on these determinants in Appendix 2.

A local-level analysis consists of two steps. Firstly, local-level epidemiological data should be assessed, for example district level incidence figures from health facilities. This can help to locate 'hotspots' of disease transmission and give some clues as to risk factors for VBDs. There is more information on how to identify 'hotspots' of transmission in order to target IVM interventions in 5.1. Secondly, environmental and human factors which may be influencing disease on smaller scale should be identified.

### 3.3.1 Step 1: Investigate epidemiological data (lower administrative level)

Regional vector control programmes should be familiar with the incidence / prevalence of disease within their region. Sources of data include health management information system (HMIS) data, health centre records, out-patient or in-patient records from health facilities or community surveys (for diseases such as human African trypanosomiasis or onchocerciasis where patients often do not present at health facilities). Are there differences in disease incidence / prevalence by geographic area or over time? Also it is helpful to consider whether there are differences in disease incidence / prevalence by for example age, sex, ethnic group, occupation, community or according to whether people use preventive measures. This can help identify human risk factors for disease transmission. If these data are not collected routinely, these types of questions could be added to hospital logs or survey forms. Sudden changes in epidemiological data may be a result of changes in diagnostic practice or reporting and so it is important to rule this out before taking any action.

Surveillance should be strengthened to capture data on emerging or re-introduced infections or diseases.

### 3.3.2 Step 2: Consider other environmental factors, alternate hosts and human factors which may be influencing disease

A number of environmental and human determinants can influence VBD (outlined in Appendix 2). Vector control programmes at provincial level should have an indication of what natural features there are (e.g. rivers, lakes, forests, wetlands), land use (e.g. plantations, rice or cotton agriculture)

and the presence and distribution of alternate hosts (e.g. livestock, wild animals). It may be helpful to think in terms of ecosystems present since this will give an indication of the likely disease-vector complexes, although within a province there may be several ecosystems. More information on common ecosystems is given in Box 3.1. Areas of economic or socio-political instability, such as camps for displaced people should also be a priority for VBD assessment and intervention.

Identifying human determinants of VBD such as socio-economic conditions, population movement, practices and attitudes towards VBD and access to diagnosis and treatment is important. Provincial level VBD control programmes should largely be aware of these determinants. However, from time to time it may be useful to hold a meeting with community stakeholders such as village chiefs, religious leaders and community groups, particularly if there are changes in epidemiological parameters.

**Figure 3.13: Participatory research – generating a seasonal calendar** (photo courtesy of S. Lindsay)

An extension of a simple consultation meeting would be to use participatory mapping whereby stakeholders such as village chiefs, religious leaders and community groups help to map variables such as where people live, the patterns of their movements, infrastructure (e.g. roads, locations of markets and schools), vector breeding sites, locations of health services, land use, vegetation and water bodies. Similarly, stakeholders can help to generate a seasonal calendar including information on the timing of peaks of disease incidence, when people move (e.g. religious festivals) and timing of the main agricultural activities (e.g. planting, harvesting, or movements of livestock) (Figure 3.13). Participatory and temporal mapping can help to identify VBD risks and periods of increased risk and improve targeting of control.

An added advantage of these participatory processes is that they can lead to community empowerment, increased understanding of disease risks and compliance with control measures. More examples, of community participation and its value in IVM are given in Chapter 5, including for example involvement of school children in malaria control in Khartoum, Sudan and Chapter 8, including use of community resource persons to operationalise LSM in Dar es Salaam, Tanzania.

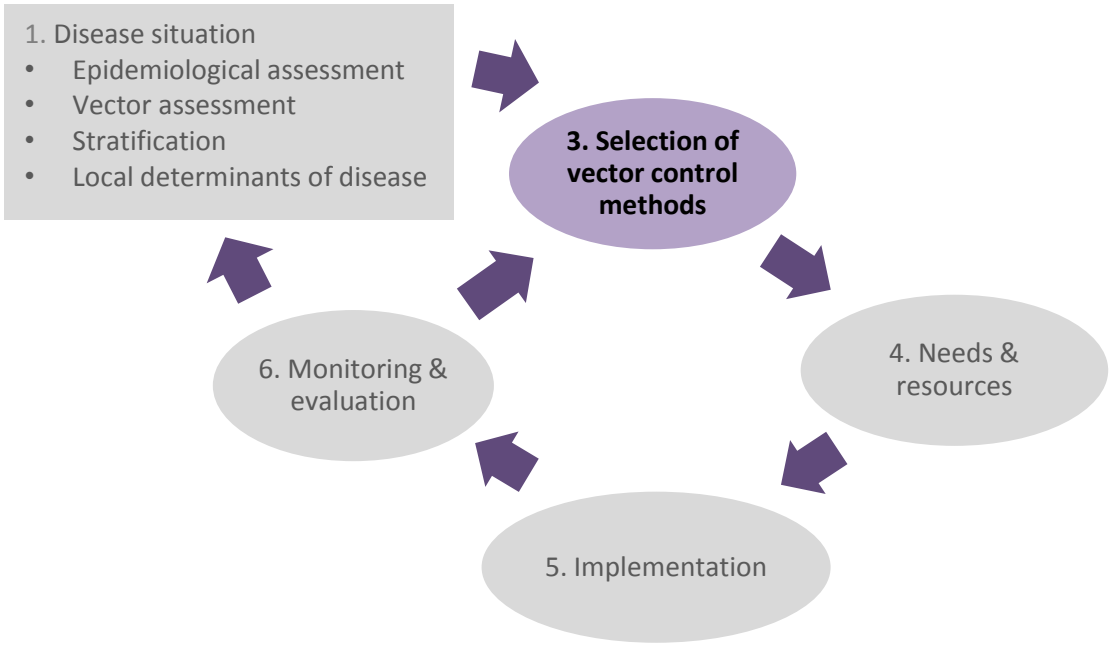
**KEY POINT**

If there appears to be a 'hotspot' of disease, consider that this may be caused by failings in the current disease control system before considering additional methods. For example, health centres may be prescribing ineffective drugs, or there may be low coverage or non-compliance with preventive measures.

**CHAPTER SUMMARY**

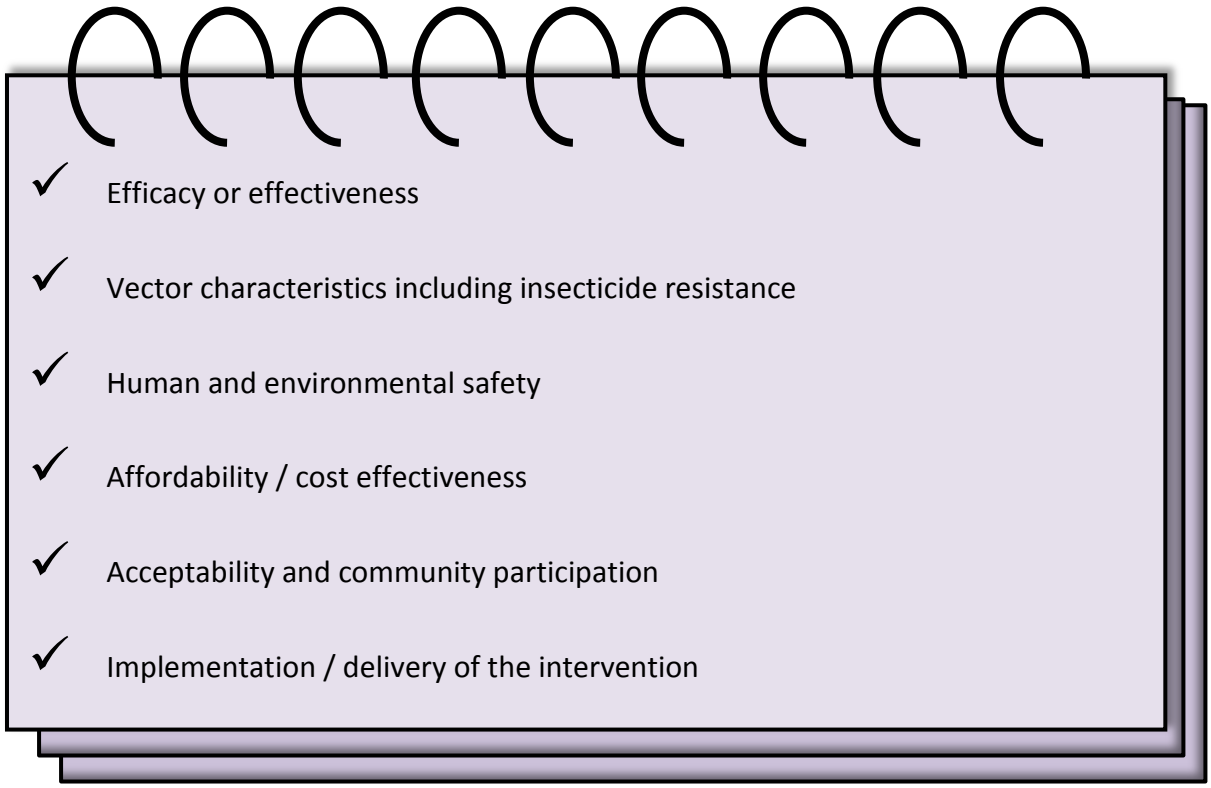
- Understanding the distribution of diseases and vectors is necessary in order to plan control efforts and prioritise resources.
- A disease assessment should be conducted in two stages – i) broad-level analysis and stratification (provincial level) and ii) local-level analysis (district and below).
- A broad-level analysis consists of assessing disease endemicity maps, province-level epidemiological data and vector distributions. Programmes can then classify provinces according to diseases present, their incidence, vector species and ecology.
- A local level analysis involves assessing the micro-epidemiology of the disease including district / community level epidemiological data, as well as local-level environmental and human determinants.

# 4 Selection of vector control methods




## 4.1 What factors need to be considered when selecting vector control tools?

The main factor when deciding on vector control tools is the effectiveness of the tool in reducing disease or infection. However, other factors which need to be considered include vector characteristics (including insecticide resistance), human and environmental safety, affordability/cost effectiveness, acceptability and community participation and logistics/policy support for the intervention.



### 4.1.1 Efficacy of vector control tools against VBD

A wide range of vector control tools exist; which can be broadly classified into chemical-based and non-chemical based tools for control of either adult or immature forms of the vector. This chapter provides guidance on what vector control interventions should be implemented. Previous guidance on vector control has not included detail on tool efficacy and assumes that all tools are equally effective, which is not the case. In many situations we lack the evidence that some vector control tools in common use today are actually effective. In this Toolkit we only recommend vector control tools that have been shown to be effective because one of the central tenets of IVM is to make evidence-based decisions. In assessing the efficacy of vector control tools for each disease we draw on evidence from systematic reviews and meta-analyses, as well as individual studies such as randomised controlled trials (RCTs) and programme data. It is realised that there are some interesting developments on novel vector control tools but these are still experimental and therefore are not included in this Toolkit.

It is important to choose vector control tools on the basis of their **efficacy against epidemiological parameters** (prevalence or incidence of infection/disease), where possible. Evidence of efficacy against the vector may be useful in some circumstances but this does not always correlate with impact on disease and so should be viewed more cautiously.

In the following sections we have separated vector control tools into three levels:

1) Tools with a WHO recommendation for which there is strong evidence of their efficacy.

2) Tools with some evidence to recommend their use or evidence to recommend their use in certain settings or populations.

3) Tools for which there is currently insufficient evidence to recommend their use.

### 4.1.2 Efficacy of vector control tools against malaria

| Tools with a WHO recommendation | Tools with some evidence / or evidence to recommend their use in certain settings or populations | Tools for which there is currently insufficient evidence to recommend their use |
|---|---|---|
| Long-lasting insecticidal nets (LLINs) [34, 35] | House improvement / screening | Larvivorous fish |
| Indoor residual spraying (IRS) [36] | Insecticide-treated sheeting / tents / wall linings | Spatial repellents |
| Larval source management (LSM) (supplementary tool) [37] | Insecticide-treated clothing or sheets | Topical repellents |

#### 4.1.2.1 WHO recommended vector control tools against malaria

The main vector control tools effective against malaria and recommended by the WHO are long-lasting insecticidal nets (LLINs) [34, 35] and indoor residual spraying (IRS) [36], which are similarly effective. Larval source management (LSM) (Box 4.1) is recommended by the WHO as a supplementary malaria vector control methods in some specific locations where breeding sites are

'few, fixed and findable' [37]. LLINs and IRS are effective against indoor biting and resting *Anopheles* mosquitoes. LSM will serve to reduce densities of mosquitoes indoors and outdoors. There are no other recommended interventions for outdoor biting mosquitoes, except for LSM – this is an active area of research.

**Box 4.1: What is larval source management (LSM)? (Adapted from [38])**

Larval source management encompasses any of the below interventions:

- **Habitat modification** - a permanent change of land and water. It includes landscaping; drainage of surface water; land reclamation and filling; coverage of large water storage containers (for example, wells) with mosquito-proof lids and permanent slabs, building covered areas for potential breeding sites (for example, shelters for tyres) or complete coverage of water surfaces with a material that is impenetrable to mosquitoes (for example, expanded polystyrene beads.
- **Habitat manipulation** - a recurrent activity and includes water-level manipulation, flushing of streams, drain clearance, shading, proper disposal of garbage, regular emptying and cleaning of domestic containers (e.g. flower pots, animal drinking water troughs), or exposing habitats to the sun depending on the ecology of the vector.
- **Larviciding** - regular application of microbial or chemical insecticides to larval habitats to control mosquitoes (Figure 4.1).
- **Biological control** - introduction of natural enemies of mosquitoes into aquatic habitats e.g. predatory fish or invertebrates, parasites, or other disease-causing organisms.
- **Regulatory control** – e.g. removal of dangerous man-made breeding sites, safe waste disposal etc.

**Figure 4.1: Larviciding of *Anopheles* breeding sites in The Gambia** (photo courtesy of S. Lindsay)

#### 4.1.2.2 Recommendation on combined use of LLINs and IRS for malaria control

The WHO recently released a position statement on combined use of LLINs and IRS [39]. Several studies have been conducted looking at whether IRS confers an additional benefit on top of LLINs. A cluster-randomised trial in The Gambia reported no significant benefit of LLINs and IRS in comparison to LLINs alone [40]. However, a study in Tanzania did show additional benefit of LLINs and IRS although the LLIN usage in this study was much lower (between 36% and 53%) [41]. The overall conclusion is that in areas with high LLIN coverage and where LLINs remain effective, IRS may have limited utility in reducing malaria morbidity and mortality [39]. However, as part of a resistance management strategy there may be benefit in implementing both interventions together, but only if a different (i.e. non-pyrethroid) insecticide is used for IRS [39, 42]. Programmes should prioritize delivering either LLINs or IRS at high coverage and to a high standard rather than introducing the second intervention as a means of compensating for deficiencies in the implementation of the first [39].

#### 4.1.2.3 Vector control tools with some evidence to recommend their use for malaria / or in specific settings/populations

A large number of studies have shown that improved housing such as closing eaves, ceilings and installing screening on doors and windows can reduce mosquito numbers in the home and malaria [43]. A RCT in The Gambia found lower mosquito densities and lower prevalence of anaemia among inhabitants of screened homes compared to control homes; with fully screened homes (screened windows and doors and closed eaves) performing better than partially screened homes (installation of screened ceilings only) [44].

Insecticide-treated plastic sheeting may have benefit in temporary settlements such as refugee camps. A RCT conducted in refugee camps in Sierra Leone found a 61% protective efficacy against malaria of deltamethrin-treated plastic sheeting attached to the walls and ceilings of temporary shelters compared to untreated sheeting [45]. A controlled before-and-after study which compared insecticide-treated plastic sheeting versus untreated plastic sheeting for construction of temporary labour camps in India showed a 96% (95% CI: 70% - 99%) reduction in malaria incidence [46]. Insecticide-treated plastic sheeting should be applied to both walls and ceilings of these shelters for maximum effect. Insecticide-treated plastic sheeting has also shown some benefit when used as wall linings in houses. An RCT in India reported a 71% (95% CI: 47% - 84%) reduction in malaria incidence in a village in which deltamethrin-treated plastic wall and ceiling linings were installed compared to a village not using these plastic linings [47].

Studies of insecticide-treated clothing, shawls and bedsheets have also shown promise in preventing malaria. A study in Kenya reported a 81% reduction in malaria cases in the group using permethrin-impregnated shawls (shukas) compared to the control group [48]. An RCT assessing the use of permethrin-treated clothing and bedding among refugees in Kenya found a 69% reduction in clinical malaria [49]. Insecticide treated clothing or sheets are advantageous over topical repellents in that their use may be more consistent although re-treatment with insecticides will be required at regular intervals.

#### 4.1.2.4 Vector control tools with currently insufficient evidence to recommend their use for malaria

Fish are able to reduce mosquito larval densities in breeding sites [50]. However, a systematic review of larvivorous fish as an intervention against malaria found no convincing evidence that fish suppress larval populations to an extent whereby they reduce malaria in the local human population [51].

Spatial repellents such as mosquito coils are commonly purchased by households to reduce mosquito nuisance. Although many studies have shown beneficial effects of mosquito coils on mortality, deterrence, repellency and feeding inhibition in both laboratory and semi-field environments, evidence against clinical outcomes is weak. Further research on new forms of spatial repellents, such as passive emanators is being conducted.

A meta-analysis of the efficacy of personal repellents against malaria did not show any effect against either *Plasmodium falciparum* malaria (PE 18%, between -8% and 38%) or *P. vivax* malaria (PE 20%, between -37% and 53%) [52]. Given the limited evidence we do not recommend the routine use of personal repellents against malaria in endemic populations, although they can help reduce biting nuisance for individuals.

**KEY POINT**

**The key vector control interventions we recommend for control of malaria are LLINs and/or IRS.** The selection of these should be based on local epidemiology and the insecticide resistance profile. LSM can be a useful supplement to core interventions but its use is only recommended in some specific locations where breeding sites are 'few, fixed and findable'.

Other interventions to consider as part of an integrated strategy or in specific settings/populations are housing improvements such as screening, insecticide-treated walling lining and plastic sheeting for temporary structures and insecticide-treated clothing and bedsheets.

### 4.1.3 Efficacy of vector control tools against lymphatic filariasis

| Tools with a WHO recommendation | Tools with some evidence / or evidence to recommend their use in certain settings or populations | Tools for which there is currently insufficient evidence to recommend their use |
|---|---|---|
| (Preventive chemotherapy* [53]) | LLINs (anophelines) | LLINs (culicines) |
| | IRS (anophelines) | IRS (culicines) |
| | House improvement / screening (anophelines) | |
| | LSM (culicines) | |
| *except where *Loa Loa* is co-endemic | | |

#### 4.1.3.1 Vector control tools with some evidence to recommend their use for lymphatic filariasis / or in specific settings/populations

The primary intervention against lymphatic filariasis (LF) is preventive chemotherapy (Mass drug administration, MDA) with either ivermectin or diethylcarbamazine citrate (DEC) in combination with albendazole [53]. However, the role of vector control is increasingly recognised as part of an integrated strategy and is the only method possible in areas where *Loa Loa* is endemic [54, 55]. Combining MDA and vector control has several advantages including supressing transmission without the need to identify all foci of infection and minimising the risk of re-establishment of transmission from positive individuals [55].

Since malaria and LF share the same *Anopheles* vector in rural areas, we would expect LLINs to be effective against both diseases. To our knowledge, no RCTs have addressed this question. However, observational studies in Papua New Guinea and Nigeria have shown a beneficial effect of insecticide-treated nets (ITNs) on LF transmission where the disease is transmitted by *Anopheles* mosquitoes [56-59] and LLINs may be particularly useful in areas co-endemic for LF and *Loa Loa* where MDA with ivermectin is contraindicated due to serious adverse events [60].

House spraying with residual DDT alone led to interruption of transmission of LF by *Anopheles* mosquitoes in the Solomon Islands [61] and Indonesia [62]. In both of these cases, use of DDT IRS and elimination of LF was a by-product of the malaria control programme. Although this evidence is convincing, few other studies have been conducted and the efficacy of other residual insecticides has not been rigorously tested. In addition, given the long lifespan of the adult filarial worms (estimated to be between 4 and 10 years), IRS would need to be implemented consistently for an extended period (as in the study in the Solomon Islands) which may not be feasible in some settings.

LSM, whether this is microbial larvicide, environmental management or polystyrene beads has also been shown to be effective against culicine vectors of LF. These interventions are well adapted to target the breeding sites of *Culex* vectors which predominate in urban and semi-urban environments. Treatment of enclosed water bodies such as latrines with a floating layer of expanded polystyrene beads can prevent mosquito breeding for extended periods [63-65] (Figure 4.2).

Treatment of open breeding sites (e.g. drains) with insecticides such microbial larvicides (e.g. *Bacillus thuringiensis israelensis* (*Bti*) and *Bacillus sphaericus)* [66-70] or insect growth regulators (e.g. pyriproxyfen) [71] has also been shown to reduce mosquito breeding. Importantly, several studies have shown the additional benefits of LSM in addition to MDA on microfilarial infections. In Makunduchi, a town in Zanzibar, Tanzania a single MDA with DEC combined with treatment of pit latrines with polystyrene beads was followed by a progressive decline in the microfilarial rate from 49% to 3% [72]. The added contribution of vector control to this decline in microfilarial rate was shown by comparison with another town where only MDA was implemented and where infection resurged 3-6 years after the MDA campaign. In this campaign, biting nuisance was also reduced which greatly increased public appreciation of the programme [73]. Several studies from India have also shown beneficial effects of multiple LSM strategies (e.g. larviciding, polystyrene beads and fish) against microfilaraemia [74-76] .

**Figure 4.2: Treatment of latrines with expanded polystyrene beads** (courtesy of J. Ensink)

Given that house improvement such as closing the eaves and installing screening is able to reduce house entry of *Anopheles* mosquitoes [43], we would also expect this intervention to be effective against LF in rural areas.

#### 4.1.3.2 Vector control tools with currently insufficient evidence to recommend their use for lymphatic filariasis

LLINs and IRS are less effective against culicine vectors of LF because *Culex* mosquitoes are more robust vectors that are less susceptible to insecticides than *Anopheles* [77-79]. For example, a study by Bøgh *et al.* reported that ITNs reduced indoor resting density of *Cx. quinquefasciatus* by 16% compared to a 98% reduction in *Anopheles* species [80]. A study in India did not show any effect of bendiocarb IRS on the density of *Cx. quinquefasciatus* [81]. To the best of our knowledge, no studies have assessed the efficacy of LLINs or IRS against clinical parameters of LF transmitted by culicines and therefore there is insufficient evidence to recommend these interventions. Insecticide resistance in culicine mosquitoes has also been reported in some countries such as Zanzibar which may limit the utility of LLINs and IRS should vector control be implemented as part of an elimination programme alongside MDA [82].

**KEY POINT**

In combination with MDA, we recommend the following vector control interventions for lymphatic filariasis:

- LLINs (and possibly also IRS where there is a commitment to implement repeatedly for an extended time period) where anophelines are responsible for transmission

- LSM where culicines are responsible for transmission.

### 4.1.4 Efficacy of vector control tools against dengue

| Tools with a WHO recommendation | Tools with some evidence / or evidence to recommend their use | Tools for which there is currently insufficient evidence to recommend their use |
|---|---|---|
| SUSTAINED MANAGEMENT | | |
| Indoor spraying (preferably with residual insecticides) | | Aerial and truck mounted ULV space spraying |
| Perifocal spraying e.g. tyres with residual insecticides | | |
| Container removal | | |
| Water container covers | | |
| Container larviciding (insecticides or biologicals) | | |
| Social mobilisation campaigns (education / public relations) | | |
| Legislation (enforcement and incentives) | | |
| Environmental management | | |
| LLINs, insecticide treated curtains/screening | | |
| EPIDEMIC MITIGATION | | |
| Indoor ULV space spraying | | Aerial and truck mounted ULV space spraying |
| IRS | | Topical repellents |
| LLINs, insecticide treated curtains/screening | | |
| Legislation (e.g. granting immediate access to premises) | | |

Vector control tools for dengue can be split into those used for sustained management of vectors and those used for epidemic mitigation, when an outbreak has occurred and the aim is to prevent more dengue cases [83]. Unfortunately, the evidence base on vector control is hampered by a lack of methodologically strong studies able to attribute declines in cases/vector populations to vector control interventions used and studies with entomological endpoints (especially those that do not correlate well with adult density), rather than epidemiological endpoints. Vector control tools for dengue recommended in this section are based on a critical assessment carried out by dengue experts as part of the Partnership for Dengue Control Initiative [83] (www.controldengue.org/) based on WHO –recommended tools [84]. The critical assessment concluded that the experts were not able to recommend a specific intervention because of the limitations of the data, in particular the absence of data showing a clear positive health impact. It should also be noted that there is no or little evidence available on dengue interventions which have been tested in Africa and therefore it is important to learn lessons from other countries and continents where there is a large amount of experience on dengue control.

#### 4.1.4.1 WHO recommended vector control tools against dengue

#### 4.1.4.1.1 Sustained management

IRS for sustained management of dengue vectors has only been conducted on a few occasions. However, studies in Cairns in Australia show that IRS is able to reduce adult female density [85] and can reduce dengue virus (DENV) transmission risk when used appropriately [86].

Perifocal spraying of containers using residual insecticides for control of larvae and adult resting mosquitoes has been shown to be successful in two *Aedes aegypti* eradication programmes from the Australian Northern Territories in the 2000's [87].

Environmental management methods such as container removal or washing, bleaching containers, or covering containers with lids, usually done in combination and with community mobilisation and participation for increased sustainability have been shown to reduce entomological parameters in the large number of studies [88-93]. More recently, studies in Latin America have shown beneficial effects of insecticide-treated net covers for containers (in combination with insecticide-treated curtains) on larval and pupal demographic indices [94, 95].

Treatment of containers using chemical (e.g. temephos) or microbial (e.g. *Bti*) larvicides has been shown to reduce entomological parameters in a number of studies [96-98]. A systematic review [99] identified one study in Cambodia which reported a 53% protective efficacy (95% CI: 50-55%) of water treatment with temephos against dengue incidence [100]. A systematic review of the effectiveness of *Bti* when used as a single agent for the control of dengue vectors [101] identified fourteen studies, of which twelve reported reductions in entomological indices with an average duration of control of 2-4 weeks. The review identified one study which looked at dengue incidence which reported a single dengue case in the *Bti* area compared to 15 cases in the untreated area when an outbreak occurred [102]. More recently, a study of targeted treatment of productive breeding sites with spinosad and long-lasting insecticidal net screens showed lower adult and pupal-based vector indices compared to control (no intervention) [103].

Studies show that larval predators e.g. lavivorous fish, copepods, insects are able to reduce *Ae. aegypti* larval indices, although whether this translates into an effect on adults or dengue incidence is unclear. A meta-analysis of nine biological control studies resulted in an average reduction in container index of 82% (95% CI: 56 – 93%) [99].

As mentioned, community mobilisation and participation in dengue control is crucial given that many of the breeding sites are local to households and tied in with daily activities and that sustainability of efforts is key to long term *Ae. aegypti* vector management strategies. A number of studies have shown beneficial effects of community-based dengue control e.g. education campaigns, social mobilisation [90, 104-106].

Use of legislation as a component of sustained mitigation programmes was considered to be effective by the expert panel [83]. Legislation for dengue control can include holding citizens and local government directly responsible for failing to deal with breeding sites around the home or making local authorities responsible for maintaining drains, water courses or swamps and canals within their administrative limits, and in particular imposing penalties if they don't comply. Legislation has been used to good effect for dengue control in Singapore [107] and similar legislation has been promulgated in other areas, including for example Sindh Province, Pakistan and Sri Lanka.

A systematic review suggests that LLINs, insecticide-treated curtains and screening may be effective against dengue [108] with several studies reporting reductions in entomological parameters[94, 109-111] and one study reporting a high protective efficacy of insecticide-treated screening against IgM seropositivity [112, 113]. These interventions are most likely to be in place for sustained management but could also be rolled out for epidemic control. Studies suggest that high coverage of insecticide-treated interventions in the home (~70%) are required to generate a community-level effect against dengue vectors [111].

A review looking at the efficacy of biological methods, chemical methods, environmental management or a combination of these methods found that combinations are most effective [99]. In conclusion, a package of vector control interventions against dengue is advised, ideally combining chemical and environmental methods or biological and environmental methods. In addition, methods should ideally target both the immature and adult stages of the vector.

#### 4.1.4.1.2 Epidemic control

Indoor ultra-low volume (ULV) insecticide application usually administered using portable handheld or backpack sprayers has been shown to reduce the number of dengue cases in Iquitos, Peru if applied early in the epidemic transmission season [114]. IRS has also been used successfully for epidemic control in Brazil and Hawaii [86, 115]. Implementing interventions in the household can be operationally difficult during outbreaks, particularly in large settlements, where it may be difficult to gain access to sufficient houses to achieve high intervention coverage in a short period of time [83].

### 4.1.4.2 Vector control tools with currently insufficient evidence to recommend their use for dengue

The expert group recommends the use of topical repellents, alongside IRS for epidemic control [83]. However, to the best of our knowledge there are no studies of topical repellent for dengue control with epidemiological outcomes and evidence from a systematic review on malaria suggests that topical repellents will not be effective against disease outcomes [52].

The expert review does not recommend the use of aerial or truck mounted ULV since this has no sustained impact on mosquito populations and is not cost effective for routine delivery during outbreaks [83, 116, 117]. Use of aerial or truck mounted ULV is often politically motivated as they are highly visible interventions. However, the killing effect is transient and mosquito populations can recover rapidly and efficacy is variable because droplets may not penetrate inside houses to where *Ae. aegypti* are resting [118, 119], especially if householders don't comply with requests to open their doors and windows [120].

**KEY POINT**

For dengue vector control we recommend using a **combination** of vector control methods.

Ideally these methods should span 2 or more categories (chemical, biological or environmental) and should target both immature and adult vectors.

### 4.1.5 Efficacy of vector control tools against cutaneous and visceral leishmaniasis

| Tools with a WHO recommendation | Tools with some evidence to recommend their use | Tools for which there is currently insufficient evidence to recommend their use |
|---|---|---|
| IRS (where vectors bite or rest indoors) | Environmental modification | |
| LLINs / insecticide-treated curtains or screening (where vectors bite or rest indoors) | | |
| Reservoir management (zoonotic and sylvatic cycles) | | |

#### 4.1.5.1 WHO recommended vector control tools against cutaneous and visceral leishmaniasis

The efficacy of vector control tools against leishmaniasis depends on the parasite, vector and transmission cycle. However, in general we can say that if the sandfly vector is biting or resting indoors, then LLINs or IRS will be effective interventions against cutaneous or visceral leishmaniasis. For example, even vectors with a sylvatic cycle, may be feeding or resting indoors, especially if habitat change or increased human activity or urbanisation in sylvatic fringe areas has encouraged domestication of vectors. If feeding or resting is occurring away from the home then other strategies need to be considered. It is therefore hugely important to have a sound grasp of sandfly biology and human behaviour in a particular setting before planning specific intervention strategies.

**KEY POINT**

It is important to have a sound grasp of sandfly biology and human behaviour in a particular setting in order to understand where transmission is occurring or where vectors rest before planning specific intervention strategies.

A systematic review [108] identified three studies assessing the efficacy of LLINs or ITNs against cutaneous leishmaniasis transmitted by *Phlebotomus papatasi* or *P. sergenti* which reported high protective efficacies against cutaneous leishmaniasis ranging from 50% to 98% [121-123]. A study of LLINs against visceral leishmaniasis did not show a significant effect on incident *Leishmania donovani* infections or incident cases of visceral leishmaniasis in India and Nepal [124]. However, transmission was likely occurring outside the home where LLINs would not be able to prevent sandfly-human contact. Insecticide treatment of nets provides better protection than untreated nets [125], although the mesh size of nets should be considered since nets designed to be cooler which have large holes are more likely to let sandflies though, even if they are insecticide treated [126, 127]. Other insecticide-treated materials such as insecticide-treated curtains or screening have also been shown to reduce vector density within the home [128-130], although evidence of their efficacy against clinical disease is less strong than for LLINs [129, 131].

IRS is also highly effective against cutaneous and visceral leishmaniasis where vectors come indoors. For example, RCTs reported protective efficacies of 54% (95% CI: 3-78%) in Peru [132] and 47% (95% CI: 32-59%) in Afghanistan against cutaneous leishmaniasis [123]. A number of other studies and programmatic evidence from a DDT IRS anti-malaria campaign in Peru which reported drastic reductions in transmission of cutaneous leishmaniasis also supports these findings [133-135]. Similarly, there is good programmatic evidence from India to suggest that IRS is effective against visceral leishmaniasis with reductions in visceral leishmaniasis cases during DDT campaigns introduced for malaria control [136-138]. For peridomestic species, outer walls and animal accommodations should also be sprayed with IRS, as well as inside houses.

Leishmaniasis transmission can also be zoonotic, with wild animals (sylvatic zoonosis) or domestic animals (domestic zoonosis) acting as reservoir hosts. In some cases, reservoir control is recommended, alongside or to replace vector control measures. Table 4.1 outlines some of the major parasite transmission systems operating in SSA and provides guidance on potential reservoir and vector control methods (more detail in [29]). Where studies have been identified on these reservoir and vector control measures, these are cited in the table. Some of the WHO recommended methods have little or no evidence to support their use, although small-scale studies could be conducted to verify their efficacy in your setting.

**Table 4.1: Zoonotic and sylvatic transmission cycles operating in SSA and guidance on potential reservoir and vector control methods** [29]

| Disease | Parasites | Endemic countries in Africa | Reservoir hosts | Reservoir control | Vector control |
|---|---|---|---|---|---|
| Visceral leishmaniasis | *Leishmania donovani* and *L. infantum* | Eritrea, Ethiopia (Metema-Humera in the northwestern lowlands; Libo Kemkem and Fogera districts in Amhara regional State and north of Lake Turkana; in the south, the Segen and Woito valleys, the Genale and Gelana river basins and west Moyale at the border with Kenya), Djibouti, Kenya (Machacos, Kitui, West Pokot, Masinga, Meru, Baringo, Turkana), Somalia, the Sudan (North: Gadaref, Blue Nile, White Nile, Sinnar, South Kordofan and West Darfur states; South: Upper Nile, Jonglei, Unity States, Eastern Equatoria) and Uganda (northeastern focus: Pokot Department) | *L. donovani* mainly anthroponotic.<br><br>Foci of zoonotic transmission related to *L. infantum* with domestic dogs as main reservoir. | No recommendations | IRS and LLINs |
| | | | | | Not recommended: spraying of termite hills to control *P. martini* |
| Visceral leishmaniasis | *L. infantum* | Algeria, Chad, Central African Republic, Egypt, Gambia, Libyan Arab Jamahiriya, Mauritania, Morocco, Senegal and Tunisia | Domestic dogs and wild canines (foxes, jackals, wolves). | Management of domestic and feral dog populations through treatment or culling [139, 140]. | Topical insecticide on dogs or insecticide-treated collars may have some benefit [141].<br><br>IRS if species are endophilic. |
| Cutaneous leishmaniasis (few or sporadic cases | *L. tropica* | Algeria, Egypt, Ethiopia, Israel, Jordan, Kenya, Libyan Arab Jamahiriya, Morocco, Namibia, and Tunisia | Suspected to be zoonotic. Hyraxes are among suspected reservoir hosts | No recommendations | No recommendations |
| Epidemic zoonotic | *L. major* | Algeria, Burkina Faso, Cameroon, Chad, Egypt, Ethiopia, Gambia, Ghana, Guinea, Guinea | Four main transmission systems: *R. opimus* (great | Studies of poisoned baits to control the | No recommendations |

| | | | | | |
|---|---|---|---|---|---|
| cutaneous leishmaniasis | | Bissau, Kenya, Kuwait, the Libyan Arab Jamahiriya, Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, the Sudan and Tunisia | gerbil) and *P. papatasi*; *Psammomys* spp. (fat sand rats) and *P. papatasi*; *Meriones* spp. (jirds) and *P. papatasi* or *P. salehi*; and *Arvicanthis*, *Tatera* or *Mastomys* spp. and *P. duboscqi* or *P. papatasi*. | rodent have been shown in a number of studies to reduce cases of zoonotic CL [142-144]. Deep ploughing or other mechanical destruction of rodent habitats has been tested in a number of countries (e.g. [145]) but is expensive and not sustainable. | |
| Zoonotic cutaneous leishmaniasis | *L. aethiopica* | East Africa Highlands: Ethiopia, Kenya, Uganda | Stable foci of low endemicity are maintained by hyraxes (*Procavia, Heterohyrax* and *Dendrohyrax* spp.), and the parasite (*L. aethiopica*) is transmitted by *P. longipes* and *P. pedifer*. | Small scale eradication of hyraxes close to settlements | Fogging of hyrax habitats |

#### 4.1.5.2 Tools with some evidence to recommend their use against cutaneous and visceral leishmaniasis

Environmental modification through cleaning and clearing of rubbish from around houses, streets and vacant land, covering cracks and crevices in walls of buildings with plaster, asphalting streets and covering courtyards with bricks, cement or other materials may be effective to prevent sandfly breeding. Studies have shown that plastering of walls and cracks with lime or mud is able to reduce the density of visceral leishmaniasis vectors in the home but epidemiological data was not collected [146, 147]. Environmental modification may not be effective as a standalone intervention but should be considered as part of a long term strategy if sustainability can be achieved.

**KEY POINT**

If sandfly vectors bite or rest indoors, then LLINs and IRS should be effective interventions against cutaneous or visceral leishmaniasis.

Reservoir control methods should be considered if the parasite is maintained in domestic or wild hosts.

### 4.1.6 Efficacy of vector control tools against human African trypanosomiasis

| Tools with a WHO recommendation | Tools with some evidence / or evidence to recommend their use in certain settings or populations | Tools for which there is currently insufficient evidence to recommend their use |
|---|---|---|
| Traps and targets (insecticide-treated) | Insecticide-treated cattle | |
| | Aerial spraying | |
| | Sterile insect technique | |

Control of human African trypanosomiasis (HAT) relies on reduction of the parasite reservoir (human and/or animal) and/or vector control. Case detection and treatment has played a major role in efforts against Gambian HAT [148]. Vector control can contribute towards control of Gambian HAT and can play an especially important role against Rhodesian HAT which is a zoonosis. Various tools are available, including traps and targets that attract host-seeking tsetse flies, insecticide-treated cattle, aerial spraying of tsetse habitat and the sterile insect technique (SIT).

#### 4.1.6.1 WHO recommended vector control tools against human African trypanosomiasis

Traps and targets (insecticide-impregnated screens) are highly effective against tsetse flies [149]. They function by simulating hosts and attract tsetse flies to the device with odorant cues and/or visual cues such as size, shape and colour. While traps can be used for surveillance and control, targets are used only for control. Impregnation of the targets or traps with an insecticide makes them highly effective killing devices upon fly impact. Various designs of trap and target have been developed for use against particular target species in particular environments (more detail in: [148].

For example, the use of biconical tsetse traps was highly effective in Uganda [150]. Traps are highly effective but they are more expensive and difficult to construct and use, and they are more fragile than targets [148] and require more regular maintenance.

Sufficient traps need to be put in place per unit area in order to successfully reduce tsetse density. For savannah tsetse species, traps placed at a density of 4 baits (traps or targets) per sq. km. have been shown to reduce trypanosomiasis effectively [151]. For riverine species of tsetse found in Central and West Africa, traps or targets can be placed linearly at a distance of 1 trap/target per 50m [152]. Here, flies are attracted mostly to the colour of the trap/target and use of odourants is less effective [153, 154].

Recently, smaller insecticide-treated targets of 50 X 25 $cm^2$ have been found to be highly attractive to riverine species of tsetse e.g. *Glossina fuscipes fuscipes* [155, 156], in contrast to savannah flies, where reducing the target size drastically reduced the number of tsetse caught [157]. These tiny targets consist of a square of phthalogen blue polyester cloth (25x25cm) attached to fine black polyethylene mosquito netting (25x25cm) impregnated with insecticide (Figure 4.3). A study in northern Uganda found that tiny targets reduced *G. fuscipes* populations by more than 90% in 12 months [158]. A study of screening and treatment with or without vector control using tiny targets in Guinea found a lower incidence of HAT in the arm including vector control compared to screening and treatment alone [159]. Tiny targets are easy to deploy due to their small size, cheap to manufacture and probably require less maintenance than traps or larger screens. Smaller screens with netting were estimated to improve cost effectiveness by sixfold compared to standard 1m x 1m targets for control of *G. p. gambiensis* and *G. tachinoides* [155]. Studies show the insecticide on the netting is effective for up to 8 months but starts to fall after 5 months [158].

**Figure 4.3: Tiny targets for tsetse control** (photo courtesy of S. Torr)

#### 4.1.6.2 Vector control tools with some evidence to recommend their use against human African trypanosomiasis

Use of insecticide-treated cattle to control tsetse has shown mixed success [160], with some successful examples [161, 162] and others which were not successful [163, 164]. This is probably because of differences in the numbers and distribution of treated cattle, area covered by the treated animals and by rapid loss of the effective insecticidal dose on the animal. Also when alternative hosts such as wildlife are abundant, the flies can feed successfully on these hosts reducing the effectiveness of the treated cattle [165]. Insecticide-treated cattle are not used widely because there are few cattle in many foci of Gambian HAT in Central and West Africa. The intervention requires continued support from farmers and sustainability may be increased if implemented in areas where tsetse also transmit livestock trypanosomes that cause nagana, for example in Uganda where Rhodesian sleeping sickness is prevalent [166]. Since tsetse preferentially land on the legs and belly of cattle (75-95% of tsetse), restricting the insecticide application to only the legs and belly of older cattle can be more cost effective [167, 168] and reduces risks to non-target organisms [169].

In areas where tsetse flies are widespread, large scale aerial spraying of insecticides has been conducted. Aerial spraying of insecticide has been tried for both Gambian and Rhodesian tsetse but performs better for Rhodesian sleeping sickness where woodland surrounding tsetse habitats is less dense. Suitable concentrations of endosulfan or deltamethrin were sprayed using sequential ULV aerial spraying (sequential aerosol technique or SAT) techniques over forested habitats where the flies were killed upon impact with micro-droplets of insecticide [170, 171]. Aerial spraying can be highly effective, but is costly compared to the traps and target technology and there are concerns about the environmental impact of widespread application of insecticides.

Focal and ground spraying of insecticide targeting resting sites e.g. lower branches and tree trunks and pupal development sites e.g. ant-bear holes, springhare and hyena dens has been used successfully in a number of locations including Zimbabwe and Botswana [172, 173]. In the past DDT was used but this is no longer possible due to environmental concerns. More recently, pyrethroids have been tested for bush spraying and shown to reduce tsetse catches and HAT cases [174]. Focal and ground spraying is not widely used nowadays, as implementation over large areas on a regular basis is difficult.

Once tsetse populations have been reduced to low levels, sterile insect release (SIT) can be used to eliminate the last remaining flies. SIT has been used to successfully eliminate tsetse (*Glossina austeni*) from Unguja Island, Zanzibar from 1994-97 [175]. However, this technique may not be suitable everywhere due to its high cost, logistical difficulty, the potential for reinvasion outside of island populations and doubtful feasibility in areas with multiple species. Releasing sterile males may actually increase the amount of transmission because males are vectors of human African trypanosomiasis too.

### 4.1.7 Efficacy of vector control tools against schistosomiasis

| Tools with a WHO recommendation | Tools with some evidence / or evidence to recommend their use in certain settings or populations | Tools for which there is currently insufficient evidence to recommend their use |
|---|---|---|

| | | |
|---|---|---|
| (Preventive chemotherapy with praziquantel) | | Biological control using fish |
| Provision of potable water and sanitation (WASH) | | Molluscicidal plants |
| Health education | | |
| Molluscicides | | |
| Environmental management | | |

The mainstay of control for schistosomiasis is regular preventive chemotherapy with praziquantel [53]. Other interventions which may be of importance in the control and elimination of schistosomiasis include provision of potable water and sanitation (WASH), snail control using molluscicides, environmental management or biological methods and health education to change water use habits, reduce open defecation and urination and encourage attendance for diseases screening.

#### 4.1.7.1 WHO recommended vector control tools against schistosomiasis

Given that schistosomiasis results from the unsanitary disposal of human waste and absence of safe sources of water, it is not surprising that provision of safe water and sanitation is associated with a reduction in schistosomiasis [176, 177].

A number of effective tools are available for snail control including molluscicides and environmental management [178]. Molluscicides such as niclosamide ethanolamine salt have been used successfully for snail control in schistosomiasis control programmes in Morocco, Egypt and the People's Republic of China [179-182] and niclosamide is recommended by the WHO for snail control [183]. Molluscicides are expensive when used on a large scale, requires skilled personnel, logistics and equipment [184]. Focal mollusciciding where molluscicides are targeted to transmission sites with high prevalence can be used in smaller circumscribed transmission sites. Rapid reinvasion can occur so regular treatment is necessary and it can be difficult to know where and when to treat particularly where contact with contaminated water occurs over a large area [184].

Environmental management for schistosomiasis includes alteration of the flow rate of the water (river flushing e.g., [185]), removal of vegetation or drainage at specific times of the year. Environmental management may have some disadvantages. For example, removal of vegetation may affect fish stocks and increasing the flow rate of rivers to wash away snails may perversely create breeding habitats for *Simulium* (black fly) vectors of onchocerciasis, which prefer fast flowing water. Environmental management also plays a role where man-made habitats are being created for example, through dams, man-made lakes, irrigation schemes, aquaculture etc. Where irrigation schemes are being introduced, overhead or drip irrigation may reduce the risk of increased schistosomiasis transmission associated with traditional surface irrigation [184]. In irrigated rice growing areas, multiple cropping or alternate cropping systems can be used to reduce snail habitats [184]

#### 4.1.7.2 Vector control tools with currently insufficient evidence to recommend their use for schistosomiasis control

A number of methods of biological control have been attempted. Biological control of *Biomphalaria glabrata* by competitor snails of the Ampullariidae (*Pomacea glauca, Marisa cornuarietis*) and Thiaridae (*Tarebia granifera, Melanoides tuberculata*) families has shown some success in the Caribbean [186-189]. However, there is a risk that the new colonising snails can become susceptible to the local schistosome, as occurred in Brazil [190, 191]. Snail control using fish has been tested in a number of locations including Lake Malawi and Lake Victoria but has largely been unsuccessful [192].

Several plants contain natural molluscicides (e.g. saponins from *Phytolacca dodecandra* [193, 194] and isoflavonoids from *Millettia thonningii*). However, experimental studies have not led to recommendations on these interventions due to for example toxicity or problems with large scale production [178].

### 4.1.8 Efficacy of vector control tools against trachoma

The strategy for control of trachoma consists of **s**urgery, **a**ntibiotics for treatment, **f**acial cleanliness and **e**nvironmental change (SAFE).

| **Tools with a WHO recommendation** | **Tools with some evidence / or evidence to recommend their use in certain settings or populations** | **Tools for which there is currently insufficient evidence to recommend their use** |
|---|---|---|
| Surgery | | |
| Antibiotics | | |
| Facial cleanliness | | |
| Environmental change (environmental sanitation, physical or chemical methods) | | |

#### 4.1.8.1 WHO recommended vector control tools for trachoma

The flies that transmit trachoma can be controlled by environmental sanitation or using physical or chemical methods [195]. Environmental sanitation includes provision of water and sanitation facilities and hygiene promotion (e.g. discouraging open defecation, promoting proper disposal of household waste) and has knock on benefits on a host of other diseases including childhood diarrhoea. Therefore, these interventions should be considered as a priority. Provision of latrines has been shown in a cluster randomised controlled trial to reduce trachoma prevalence by 30% in The Gambia [196]. Space spraying, spraying of residual insecticide on outside of houses where flies rest or use of fly traps can also be useful but are not considered as long term strategies. Deltamethrin spraying has been shown to reduce trachoma prevalence by over 80% in a cluster-RCT in The Gambia [196] but continuous repeat spraying will generate resistance in the flies and this is usually only considered in areas where there is an unusual and temporary increase in transmission risk [195].

### 4.1.9 Efficacy of vector control tools against onchocerciasis

Onchocerciasis can be controlled by targeting the parasite using ivermectin chemotherapy [53] and the vector using vector control measures, in particular larviciding of breeding grounds using chemical or microbial larvicides (Figure 4.4). Although the current strategy for onchocerciasis

control relies mostly on drugs it is important to note that the major reductions were brought about by a combination of drug treatment and vector control. Vector control has also re-emerged as an important strategy now that onchocerciasis is targeted for elimination.

**Figure 4.4: Larviciding for onchocerciasis control, Sanaga River, Cameroon** (photo courtesy of Didier Baleguel)

Aerial larviciding was responsible for the near-elimination of river blindness from much of West Africa (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea Bissau, Guinea, Mali, Niger, Senegal, Sierra Leone and Togo) as part of the Onchocerciasis Control Programme (OCP) from 1974 to 2002 [197]. A number of insecticides were used in rotation (chemical and microbial) to prevent development of resistance, following early development of resistance of *Simulium damnosum* to temephos and phoxim. Despite the success of the OCP there has however been resurgence in blackflies in some of the former OCP countries indicating the need for continued vector surveillance.

In 1995, the African Programme for Onchocerciasis Control (APOC) was launched in 19 African countries not covered by the OCP [198, 199]. APOC relies heavily on MDA using ivermectin, although activities are also done to eliminate the blackfly vector in Uganda, Tanzania and Equatorial Guinea, where vector control is feasible and cost-effective. Ground larviciding with environmentally safe insecticides continued for two to three years, concluding in 2005. APOC is monitoring the areas' blackfly population to confirm vector elimination.

### 4.1.10 Efficacy of vector control tools against other viral infections excluding dengue

Vector control programmes need to remain vigilant for epidemics of arboviruses that can emerge quickly infecting large numbers of people. Importantly, in the future new human pathogens may emerge transmitted by vectors [200, 201]. Since these diseases are epidemic in nature there have

been few studies which have assessed whether particular interventions are effective at controlling outbreaks. There is a little evidence on effective tools against these viral infections although some guidance based on expert opinion is given in Box 4.2.

**Box 4.2: Vector control tools for use against viral infections excluding dengue**

**Rift Valley fever:**

Many species of mosquito are able to act as vectors for transmission of the Rift Valley fever (RVF) virus and these vary between different regions [202-205]. Among animals, the RVF virus is spread primarily by *Aedes* species, which can acquire the virus from feeding on infected animals. During periods of heavy rainfall, larval habitats frequently become flooded enabling the eggs to hatch and the mosquito population to increase rapidly, spreading the virus to the animals on which they feed. LSM is the most effective form of vector control if breeding sites can be clearly identified and are limited in size and extent. During periods of flooding, however, the number and extent of breeding sites is usually too high for larviciding measures to be feasible.

**West Nile virus:**

West Nile virus (WNV) is found in Africa and maintained in nature in a cycle involving transmission between birds and mosquitoes [206, 207]. Humans, horses and other mammals can be also infected. Mosquitoes of the genus *Culex* are generally considered the principal vectors of WNV, in particular *Cx. pipiens*. WNV is maintained in mosquito populations through vertical transmission (adults to eggs). Prevention of human WNV infections depends on the development of an effective IVM programme where the virus occurs. Studies should identify local mosquito species that play a role in WNV transmission, including those that might serve as a "bridge" from birds to human beings. Emphasis should be on LSM including source reduction, water management, and larviciding.

**Yellow fever:**

Several different species of *Aedes* mosquitoes transmit the yellow fever virus [208-210]. Mosquitoes carry the virus from one host to another, primarily between monkeys, from monkeys to humans, and from person to person. The mosquitoes either breed around houses (domestic), in the forest (wild) or in both habitats (semi-domestic). There are three types of transmission cycles.

- *Sylvatic (or forest) yellow fever*: In tropical rainforests, yellow fever occurs in monkeys that are infected by wild mosquitoes. The infected monkeys then pass the virus to other mosquitoes that feed on them. The infected mosquitoes bite humans entering the forest, resulting in occasional cases of yellow fever. Most infections occur in young men working in the forest (e.g. for logging).
- *Intermediate yellow fever*: In humid or semi-humid parts of Africa, small-scale epidemics occur. Semi-domestic mosquitoes (that breed in the wild and around households) infect both monkeys and humans. Increased contact between people and infected mosquitoes leads to transmission. Many separate villages in an area can suffer cases simultaneously. This is the most common type of outbreak in Africa. An outbreak can become a more severe epidemic if the infection is carried into an area populated with both domestic mosquitoes and un-vaccinated people.

- *Urban yellow fever*: Large epidemics occur when infected people introduce the virus into densely populated areas with a high number of non-immune people and *Aedes* mosquitoes. Infected mosquitoes transmit the virus from person to person.

The risk of yellow fever transmission in urban areas can be reduced by eliminating potential mosquito breeding sites and larviciding. Application of spray insecticides to kill adult mosquitoes during urban epidemics, combined with emergency vaccination campaigns, can reduce or halt yellow fever transmission, "buying time" for vaccinated populations to build immunity.

Mosquito control programmes targeting wild mosquitoes in forested areas are not practical for preventing forest (or sylvatic) yellow fever transmission.

**Chikungunya:**

Chikungunya virus (CHIKV) is transmitted from human to human by the bites of infected female mosquitoes and occurs in a number of locations including sub-Saharan Africa (SSA) [211-214]. Most commonly, the mosquitoes involved are *Aedes aegypti* and *Aedes albopictus* [215], 2 species which can also transmit other mosquito-borne viruses, including dengue. Both *Ae. aegypti* and *Ae. albopictus* have been implicated in large outbreaks of chikungunya. In recent decades, *Ae. albopictus* has spread from Asia to become established in areas of Africa. *Ae. albopictus* thrives in a wider range of water-filled breeding sites than *Ae. aegypti*, including coconut husks, cocoa pods, bamboo stumps, tree holes and rock pools, in addition to artificial containers such as vehicle tyres and saucers beneath plant pots. This diversity of habitats explains the abundance of *Ae. albopictus* in rural as well as peri-urban areas and shady city parks. *Ae. aegypti* is more closely associated with human habitation and uses indoor breeding sites, including flower vases, water storage vessels and concrete water tanks in bathrooms, as well as the same artificial outdoor habitats as *Ae. albopictus*. In Africa several other mosquito vectors have also been implicated in disease transmission, including species of the *A. furcifer-taylori* group and *A. luteocephalus*. There is evidence that some animals, including non-primates, rodents, birds and small mammals may act as reservoirs.

The proximity of mosquito vector breeding sites to human habitation is a significant risk factor for chikungunya as well as for other diseases that these species transmit. Prevention and control relies heavily on reducing or treating natural and artificial water-filled container habitats that support breeding of the mosquitoes. This requires mobilization of affected communities. During outbreaks, insecticides may be sprayed to kill flying mosquitoes, applied to surfaces in and around containers where the mosquitoes land, and used to treat water in containers to kill the immature larvae.

For protection during outbreaks of chikungunya, clothing which minimizes skin exposure to the day-biting vectors is advised. Repellents can be also be used and people should sleep under mosquito nets at night. Basic precautions should be taken by people traveling to risk areas and these include use of repellents, wearing long sleeves and pants and ensuring rooms are fitted with screens to prevent mosquitoes from entering.

**O'nyong-nyong:**

O'nyong-nyong (ONNV) is an alphavirus which is closely related to CHIK virus but is transmitted by anopheline mosquitoes (*An. funestus* and *An. gambiae*). It has a similar clinical picture to CHIKV

(self-limiting febrile illness characterised by headache, rash, joint pain). Secondary hosts have not been formally identified although antibodies against ONNV have been found in game animals in SSA [216]. There have been sporadic outbreaks in west and East Africa, and a recent study in coastal Kenya found seropositivity rates of 56% [217]. Since the vector is shared with malaria, standard control measures such as LLINs, IRS and LSM are likely to be effective against ONNV.

### 4.1.11 Multiple diseases and multiple interventions

In areas where diseases are co-endemic, it is recommended to roll out vector control interventions that are active against both or multiple diseases. In this way, there are likely to be cost savings and greater efficiencies. Table 4.2 summarises in a matrix form recommended vector control interventions to use when diseases are co-endemic. For example, the control of *Anopheles* should lead to a reduction in malaria, LF, rift valley fever, west nile virus and o'nyong-nyong [218-221]. WHO-recommended primary vector control tools are shown in green, and supplementary methods in orange.

Combinations of interventions are likely to be more effective against a disease than a single intervention. For example, combinations of interventions with different modes of action (chemical, biological, environmental) targeting immature and adult mosquitoes are recommended for dengue control. Studies of LLINs and IRS for malaria were discussed in 4.1.2.2. For other diseases, there are fewer studies of combinations of interventions.

**Table 4.2: Matrix showing WHO-recommended vector control tools by disease** (WHO-recommended primary tools indicated in green and supplementary tools in orange)

| Intervention | LLINs | Insecticide treated curtains / screening | IRS | House improvement / screening | House repair & cleaning peri-domestic environment | LSM | | | | Insecticide treated clothing / sheets | Insecticide treated sheeting / tents/ wall linings | Indoor ULV spraying | Water and sanitation | Molluscicides | Aerial insecticide | Focal, perfocal or ground spraying | Insecticide treated traps and targets | Insecticide-treated cattle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Larvicide | Environmental management | Predator species | Polystyrene beads | | | | | | | | | |
| Malaria | | | | | | | | | | | | | | | | | | |
| Lymphatic filariasis (Anophelines) | | | | | | | | | | | | | | | | | | |
| Lymphatic filariasis (Culicines) | | | | | | | | | | | | | | | | | | |
| Dengue | | | | | | | | | | | | | | | | | | |
| Leishmaniasis | * | * | * | | | | | | | | | | | | | | | |
| Human African trypanosomiasis | | | | | | | | | | | | | | | | | | |
| Schistosomiasis | | | | | | | | | | | | | | | | | | |
| Trachoma | | | | | | | | | | | | | | | | | | |
| Onchocerciasis | | | | | | | | | | | | | | | | | | |
| Yellow fever | | | | | | | | | | | | | | | | | | |
| West Nile virus | | | | | | | | | | | | | | | | | | |
| Rift Valley fever | | | | | | | | | | | | | | | | | | |
| Chikungunya | | | | | | | | | | | | | | | | | | |
| O'nyong-nyong | | | | | | | | | | | | | | | | | | |
| *where sandfly vectors bite or rest indoors | | | | | | | | | | | | | | | | | | |

### 4.1.12 Vector characteristics, vector resistance status and risk for development of resistance

Information from the initial vector assessment on ecology and behaviour of the target species should feed into the decision on choice of vector control tools. Vector control tools may show differing efficacy against different vector species according to their biology, ecology and behaviour. For example LLINs are more effective at controlling anopheline mosquitoes than culicines and those vector species that are more endophilic than exophilic.

It is also important to consider the vector resistance status and risk for development of resistance when using insecticide-based vector control tools. Development of insecticide resistance, particularly in malaria vectors is on the increase and may eventually threaten the effectiveness of vector control [222]. At present there are few, if any, places in sub-Saharan Africa where there is no resistance to pyrethroid insecticides, the only class of insecticide currently used for impregnating bed nets. More information on types and mechanisms of insecticide resistance, the distribution of insecticide resistance in sub-Saharan Africa across vector species and how to test for insecticide resistance is given in Chapter 9.

#### 4.1.12.1 Insecticide resistance management considerations when selecting interventions

What interventions should be implemented to mitigate insecticide resistance or maintain effectiveness if insecticide resistance is already present? Insecticide resistance management (IRM) strategies are available and technical guidance has been elaborated for malaria (where the threat is greatest) in the Global Plan for Insecticide Resistance Management (GPIRM) in malaria vectors document [42]. Additional guidance including decision trees to support decision making on intervention choice will soon be available in a WHO Framework document which assists countries in developing IRM plans. The WHO website should also be consulted since this is a fast moving area. In general, IRM strategies incorporate diversifying the range of interventions used and reducing reliance on insecticides. It might be useful to learn from experiences in agricultural pest management in this regard [223].

In summary IRM options include: rotation of different classes of insecticide and using combinations of interventions. When rotating insecticides, 2, or preferably more, insecticides with different modes of action are rotated from one spray round to the next. Combinations of interventions are particularly useful in preventing selection for resistance because when 2 or more insecticide-based vector control interventions are used in a house (e.g. pyrethroids on nets and an insecticide of a different class on the walls), the same insect is likely, but not guaranteed, to come into contact with the second insecticide if it survives exposure to the first. Using a combination of DDT IRS and LLINs, that are currently treated with pyrethroids, is likely to lead to cross resistance between DDT and pyrethroids as they have the same mode of action. If LLINs and IRS are combined it is essential to use LLINs with IRS using a carbamate or organophosphate insecticide. If one suspects pyrethroid resistance, the WHO recommends using IRS with an organophosphate or carbamate insecticide, provided there is no cross resistance to these classes of insecticide [42]. If there is strong evidence of resistance against all classes of insecticide compromising malaria control then the focus should be on increasing LLIN coverage since they will still present a physical barrier to malaria vectors.

**KEY POINT**

Using a combination of DDT indoor residual spraying (IRS) and long-lasting insecticidal nets (LLINs), that are currently treated with pyrethroids, is likely to lead to cross resistance between DDT and pyrethroids. If LLINs and IRS are combined it is essential to use LLINs with IRS using a carbamate or organophosphate insecticide.

Experimental options for IRM both of which pertain to IRS and are yet to be fully tested are i) mosaic spraying (insecticides of different classes are used in neighbouring geographic areas) and ii) use of mixtures (insecticides of different classes are mixed to make a single formulation so that the mosquito is guaranteed to come into contact with the two classes at the same time).

The GPIRM does not elaborate on the potential for **non-insecticide-based vector control interventions** to reduce vector density and pathogen transmission. However, by expanding the variety of interventions available for vector control including non-insecticide based vector control, IVM can make a real contribution to IRM and can help to prevent insecticide resistance occurring. For example, strategies such as LSM or environmental management can be used in some settings to reduce mosquito numbers without the need for insecticides and so reduce selection pressure on insecticides. For example, the risk of vectors developing resistance to *Bacillus thuringiensis israeliensis* which contains four toxic proteins is considered minimal [224].

The risk of development of resistance will be affected by the volumes of insecticides used, frequency of application and other factors. Insecticide use in other programmes and sectors may be contributing to selection pressure for insecticide resistance. Communication between VBD control programmes and between the health sector and other sectors e.g. cotton and rice growers should therefore be encouraged to determine what insecticides and in what volumes are being used where. Insecticide use in one VBD control programme may be having inadvertent effects on other vectors and so here communication is very important.

**KEY POINT**

It is important to remember that strategies such as LSM or environmental management can be used in some settings to reduce mosquito numbers without the need for insecticides and so reduce selection pressure on insecticides.

### 4.1.13 Human and environmental safety

Another consideration when deciding on vector control methods is the risk of the intervention to human and environmental health. Some known side effects of vector control methods are outlined in Table 4.3.

**Table 4.3: Side effects of vector control methods (adapted from [32])**

| Method | Side effects | Importance |
|---|---|---|
| **Chemical methods:** | | |
| Long lasting insecticidal nets / insecticide-treated curtains | Risk of resistance | + |
| | Human toxicity | - |
| | Ventilation | + |
| Indoor residual spraying | Risk of resistance | + |
| | Human toxicity | +- |
| | Smell | + |
| | Residue on walls | +- |
| | Effect on ecosystems | - |
| Indoor ULV space spraying | Risk of resistance | +- |
| | Human toxicity | +- |
| | Effect on ecosystems | - |
| Insecticide-treated sheeting / tents / wall linings | Risk of resistance | + |
| | Human toxicity | - |
| Insecticide treated clothing or bedsheets | Risk of resistance | +- |
| | Human toxicity | +- |
| Insecticidal treatment of habitat e.g., focal, perifocal, ground or aerial spraying | Effect on ecosystems | ++ |
| | Risk of resistance | + |
| Insecticide-treated cattle | Human toxicity (food chain) | +- |
| | Effect on ecosystems | +- |
| Sterile insect technique for HAT | Effect on ecosystems | + |
| Insecticide-treated traps and targets | Animal/human toxicity | +- |
| | Effect on ecosystems | +- |
| Pit latrine treatment | Effect on ground water | +- |
| | Environmental pollution (polystyrene beads) | +/- |
| **Non chemical methods:** | | |
| Source reduction | Effect on ecosystems | - |
| Habitat manipulation | Effect on ecosystems | - |
| Irrigation management | Effect on ecosystems | - |
| Design of irrigation structures | None | |
| House improvement / screening | Reduced ventilation | +- |
| Pit latrine adaptation | None | |
| Waste water management | None | |
| Solid waste management | None | |
| Predation | None, if indigenous species used | |
| Biological larvicides | Risk of resistance | - |
| Repellent plants | Human toxicity | - |
| Removal trapping | None | |
| Zooprophylaxis | None | |
| Polystyrene beads | Pollution | - |

-, not important; ±, somewhat important; +, important; ++, very important

The judicious use of pesticides is essential given the development of insecticide resistance, scarcity of new compounds under development, high costs of many insecticides and possible adverse effects

on human health (through acute or chronic exposure) and the environment (e.g. other arthropods, fish). Guidance on decision making for the judicious use of insecticides is provided by WHOPES [225]. Guidelines on distribution and use of pesticides should be followed in order to minimise potential health and environmental risks [226]. Countries should aim to reduce and eventually phase out use of persistent organic pollutants (POPs) including DDT according to the aims of the Stockholm Convention on POPs (http://chm.pops.int/Home/tabid/2121/Default.aspx). IVM offers an opportunity to reduce use of DDT by utilising alternative insecticides for chemical-based control and diversifying the interventions available for vector control.

Non-chemical methods have limited side effects, with the possible exception of certain structural adaptations that introduce changes in human work load or that affect the ventilation in houses.

#### 4.1.13.1 Affordability and cost effectiveness

Affordability is another consideration in selecting vector control methods. Affordability refers not only to national or decentralized budgets allocated to health, but also to the contributions of other sectors and the willingness of communities to invest time and resources.

Cost effectiveness is a form of economic analysis (Box 4.3). There are limited data on cost effectiveness for interventions other than LLINs, IRS and LSM for malaria control [227].

**Box 4.3: What is cost effectiveness?**

Cost effectiveness is a form of economic analysis. It compares the relative costs and effects of two different courses of action. The incremental cost effectiveness ratio or ICER is the ratio of the change in costs to incremental benefits of an intervention.

The equation is: $ICER = (C1 - C2) / (E1 - E2)$

where C1 and E1 are the cost and effect in the intervention group and where C2 and E2 are the cost and effect in the control group.

Costs are usually described in monetary units while the effect is measured in terms of lives, cases or disability adjusted life years (DALYs) gained or lost.

A review has shown that from a provider perspective, the median incremental cost effectiveness ratio (ICER) per disability adjusted life year (DALY) averted was $27 (range $8.15-$110) for ITNs and $143 (range $135-$150) for IRS. Despite variations in delivery costs between studies and settings, these interventions were consistently cost-effective against a threshold of $150 per DALY averted. This review was not able to conclude whether ITNs were more cost effective than IRS. However, three studies comparing ITNs and IRS head-to-head showed that ITNs are more cost effective than IRS[228-230], and one study found that IRS was more cost-effective than ITNs where malaria was epidemic [231]. It should be recognised that cost effectiveness of IRS is heavily dependent on the cost of insecticides, with some insecticides being considerably more expensive than others – i.e., carbamates and organophosphates are substantially more expensive than pyrethroids.

Behaviour change campaigns and other activities need to be taken into account when calculating cost effectiveness. Often these campaigns increase use and coverage to the extent that even with

the increased cost of additional activities, cost effectiveness is higher. Box 4.4 provides an example of cost effectiveness of LLIN distribution and hang-up campaigns in Ghana.

**Box 4.4: Cost effectiveness of distribution and hang-up activities - evaluation of a universal LLIN distribution campaign in Ghana (adapted from [232])**

Ghana launched a national universal mass distribution of LLINs between May 2010 and October 2012 and distributed 12.5 million LLINs. The campaign involved a number of activities including pre-registration of persons and sleeping spaces, distribution of LLINs door to door with 'hang up' campaigns by volunteers and 'keep up' behaviour change communication activities to achieve high and sustained use of the LLINs.

A study assessed the cost and cost-effectiveness of the LLIN campaign in three regions of Ghana (Brong Ahafo, Central and Western). The evaluation used a before-and-after design. The incremental cost-effectiveness of the 'hang-up' component could be assessed using data on variation in the extent to which the 'hang-up' campaign was implemented and LLIN use. Economic costs were estimated from a societal perspective assuming LLINs would be replaced after 3 years, and included the time of unpaid volunteers and household contributions given to volunteers.

In total 3.6 million campaign LLINs were distributed and 46% of households reported that that LLINs received were hung-up by a volunteer. The financial cost of the campaign was 6.51 US$ per LLIN delivered and the average annual economic cost was 2.90 US$ per LLIN delivered. It cost 6,619 US$ per additional child death averted by the campaign. Hang-up activities constituted 7% of the annual economic cost, though the additional financial cost was modest given the use of volunteers.

Importantly, it was shown that LLIN use was greater in households in which one or more campaign LLINs were hung by a volunteer – with more than 1.5 times the odds of the LLIN being used. The additional economic cost of the hang-up activities was USD 0.23 per LLIN delivered, and achieved a net saving per LLIN used and per death averted.

In this campaign, hang-up activities were estimated to be cost saving if hang-up increased LLIN use by 10% or more. This suggests hang-up activities can make a LLIN campaign more cost-effective.

Cost effectiveness during routine vector control may be different from cost effectiveness during elimination campaigns or epidemics. For example during intense epidemics, IRS carried out by experienced sprayers is probably the most rapid tool to contain transmission and is likely to be more cost effective than LLINs.

An economic evaluation was carried out of environmental management against malaria (clearing vegetation, modifying river boundaries and draining swamps) in copper mining communities in Zambia [227, 233]. The cost per DALY averted was 762$, with declining costs (32 - 133$) after the 5 year start-up period. In the long run, this intervention is likely to be cost effective, despite high start-up costs.

No studies have assessed the cost effectiveness of LSM. One study has however estimated the economic and financial costs per person protected per year for large-scale LSM using microbial larvicides in three ecologically diverse settings [234]. The cost per person protected by larval control in this analysis ranged from US$0.79 to US$2.50, which is comparable with other malaria interventions. For example, the cost of IRS ranges from US$0.88-4.94 per person protected (2000 US$), the cost per treated net year for conventional ITNs was found to range from US$1.21-6.05 and for LLINs US$1.38-1.90 (2005 US$) [235, 236].

#### 4.1.13.2 Acceptability and community participation

It is important to consider the cultural and social context in which vector control interventions are to be implemented. Acceptability of vector control interventions by communities is key to correct use of personal protective measures and sustained interest and participation in vector control and therefore intervention effectiveness. When introducing interventions into your setting, it is a good idea to assess their acceptability to communities. This can be done using social research methods such as holding a community forum meeting or a focus group (see Box 9.5). Three examples of studies which used social research methods to determine community acceptability are provided: house screening for mosquito control in The Gambia (Box 4.5), tsetse control baits in Uganda (Box 4.6) and larviciding for malaria control in Tanzania (Box 4.7).

Community participation is a key aspect of the effectiveness of most, if not all, vector control methods. Participation ranges from adherence to interventions, such as IRS, to active involvement in environmental management. Public health education is needed before programmes start to make sure everyone understands what is being done and why. Who you engage with and how you do it depends on your local circumstances. However, in rural Africa this is typically done by consulting with and involvement of village leaders, and sometimes religious leaders, from the outset before having community meetings in the villages. Community participation is often critical for achieving coverage and for the sustainability of control activities but does require investment in communication, education and training of volunteers.

**Box 4.5: Community acceptability of house screening for mosquito control in The Gambia [44, 237]**

An acceptability study was conducted alongside a randomised controlled trial of house screening (either complete (doors and windows screened and eaves closed) or ceilings screened only) versus control in the North Bank Division, The Gambia. Screening reduced entry of *An. gambiae* at night with a 59% reduction in fully screened houses and 47% reduction in screened ceiling houses versus control houses. Also a reduction in anaemia prevalence among children of about a half in screened houses and screened ceiling houses versus control houses was observed.

Qualitative and quantitative methods were used in the acceptability study. Firstly, focus group discussions were held with a selection of householders in each trial arm to gather information on general perceptions of the types of screening and to identify the key concerns and benefits of the screening as perceived by those taking part in the trial. The results of the FGD were then used to design a questionnaire survey which was taken by a wider selection of study participants. In the questionnaire the participants were asked to choose whether to keep the screening they had been allocated, have it removed or have the other type of screening. Data collection also included durability surveys at 6 and 12 months after the screening was installed and assessment of the indoor climatic conditions.

Most of the participants recognized that screening stopped mosquitoes and other insects from entering their houses. A reduction in other animals such as bats and geckos was also noted and some participants reported sleeping more soundly as they felt more secure and screening prevented dust and dirt falling on them while they slept in times of high wind or rain. Key problems identified were difficulty in cleaning the white ceiling netting in the screened ceiling group and damage to the screened doors by children and domestic animals in the fully screened group. 9% of those with fully screened houses and 17% of those with screened ceilings said they made the house hotter. The screened houses were indeed hotter but only by half a degree Celsius hotter than control houses on average. When offered a choice of screening, most participants chose full screening regardless of whether they initially received screened ceilings, full screening, or no screening.

**Box 4.6: Community acceptance of tsetse control baits in Arua District, North West Uganda [238]**

Tsetse baits (traps or targets) are a type of control method for human African trypanosomiasis (HAT). Effectiveness of traps and targets will depend to some extent on their acceptance by community. Previously it has been shown that negative associations of communities towards traps led to damage or theft of traps, and ultimately the failure of control programmes.

A qualitative study was conducted to explore knowledge, perceptions and acceptance of tsetse baits (traps / targets) in villages where they had or had not been used previously in Arua District, North West Uganda, an area endemic for Gambian HAT. Focus group discussions were held with groups of men and women from villages that had been exposed previously to tsetse traps as part of a control programme or had not been exposed previously.

The villages which were new to traps perceived the traps negatively, associating them with witchcraft and ghosts. This was largely due to the position of traps next to the river (described as being home to ghosts) and unease about who had positioned the traps and for what purpose. Villagers that had been previously exposed to traps said they initially felt similarly anxious when first exposed to the traps but now perceived them positively and beneficial, showing that negative perceptions are prone to change over time. Most participants were aware of the purpose of the traps and being able to see insects trapped seemed to reinforce positive attitudes, particularly among women. Villagers that had been explained the purpose of the trap (either by the person setting up the trap or another community member) said this information helped them to put aside associations with supernatural powers. Participants expressed a willingness and motivation to be involved in tsetse control and villagers in the group previously exposed to traps reported contributing to tsetse control, for example by maintaining traps and cutting back vegetation around rivers).

This study reinforces the need to understand community perceptions of new interventions. Tsetse control programmes should plan and budget for community involvement at all stages e.g. sensitisation, deployment and maintenance to ensure that programmes are effective and sustainable.

**Box 4.7: Community awareness and acceptability of microbial larvicides for malaria control in a rural district of East-Central Tanzania [239]**

This study assessed the community acceptability of larviciding in Mvomero District in east-central Tanzania as part of a large cluster-randomised community-supported larviciding trial.

Data was collected using household surveys, focus group discussions (FGD) and in-depth interviews (IDI). The study was unusual in that data were collected during the baseline year of the trial meaning that participants had not yet been exposed to the larviciding intervention or observed its benefits.

Study participants were generally aware the mosquitoes transmit malaria and about two-thirds of IDI participants understood that larvae were breeding in water bodies. Participants were unaware of larviciding as a potential intervention but were generally receptive to its use after hearing a brief description of the method which was read to them by the investigator. Some respondents were worried about larvicide being applied to water bodies which are used as sources of drinking water and for other domestic purposes and some expressed concern about larvicide being washed away during the rains. Despite a generally positive reaction to larviciding, participants expressed the need for community sensitisation before implementation which would enable community members to understand its benefits and safety to humans, animals, and plants.

Respondents were asked about their willingness to contribute financially to sustain a larviciding programme. 88% of participants in the FGDs were willing to contribute a small amount of money to the program at regular intervals, e.g., 3 or 6 months with a minimum contribution of 1,000 Tanzanian Shillings (TShs.) (TShs. 1,000 is approximately US$ 0.60). However, some respondents had concerns about proper use of financial contributions from the community after some bad experiences with community-supported programmes in the past where money was not used for its intended purpose. Others said that once benefits of larviciding were observed, community members would be more willing to contribute financially.

### 4.1.14 Intervention delivery / implementation

The choice of vector control tool should also take into account the feasibility and logistics of delivering or implementing the particular intervention. Interventions can be implemented by vector control services, other sectors or the community with VBD control programme oversight. Also for some interventions, for example LLINs, a number of different delivery mechanisms exist including mass campaigns and continuous distribution through various channels. Delivery or implementation mechanisms may differ for routine and epidemic control. More information on this topic is given in Chapter 5.

#### 4.1.14.1 Assessment of product quality, efficacy and safety

The WHO Pesticide Evaluation Scheme (WHOPES) is responsible for promoting and coordinating the testing and evaluation of pesticides for public health. In its present form, WHOPES comprises a four-phase evaluation and testing programme, studying the safety, efficacy and operational acceptability of public health pesticides and developing specifications for quality control and international trade. Its recommendations facilitate the registration of pesticides by Member States. Currently, WHOPES

releases lists of recommended insecticides for IRS, ITNs and space spraying and long lasting insecticidal nets (LLINs) and larvicides which are available on the WHOPES website (http://www.who.int/whopes/en/). Countries should use only those products recommended by WHOPES and meeting the quality control specifications. Lists of approved products (LLINs, insecticides for IRS and larvicides) are available on the WHOPES website. Based on WHOPES recommendations, countries can register the product with their National Regulatory Authority.

Although products may have met WHOPES standards, it is the responsibility of National Regulatory Authorities or procurement agencies (e.g. Presidents Malaria Initiative or Global Fund) to ensure the quality of the products by conducting batch testing of products pre-shipment. Batch testing should be done in a Good Laboratory Practice (GLP) certified laboratory to check whether the products meet WHO or country specifications. This process is outlined in WHO or other (e.g. Global Fund) procurement guidelines [240]. The time required for batch testing needs to be figured into leads times to ensure there is no delay in release of products for use in the field.

It is important to ensure that products delivered to the field are of good quality. Guidelines for appropriate storage and shelf lives should be adhered to. However, products that have passed their shelf life can still be used for up to 6 months as long as batch testing shows they still meet specifications. Quality assurance procedures should be put in place to ensure delivery of high quality interventions in the field – for example, checking the level of insecticide on a random sample of sprayed surfaces for IRS. An insecticide quantification kit will soon be available which can assess the level of insecticide on sprayed surfaces. Quality assurance indicators should be added to strategic plans and logical frameworks for monitoring and evaluation.

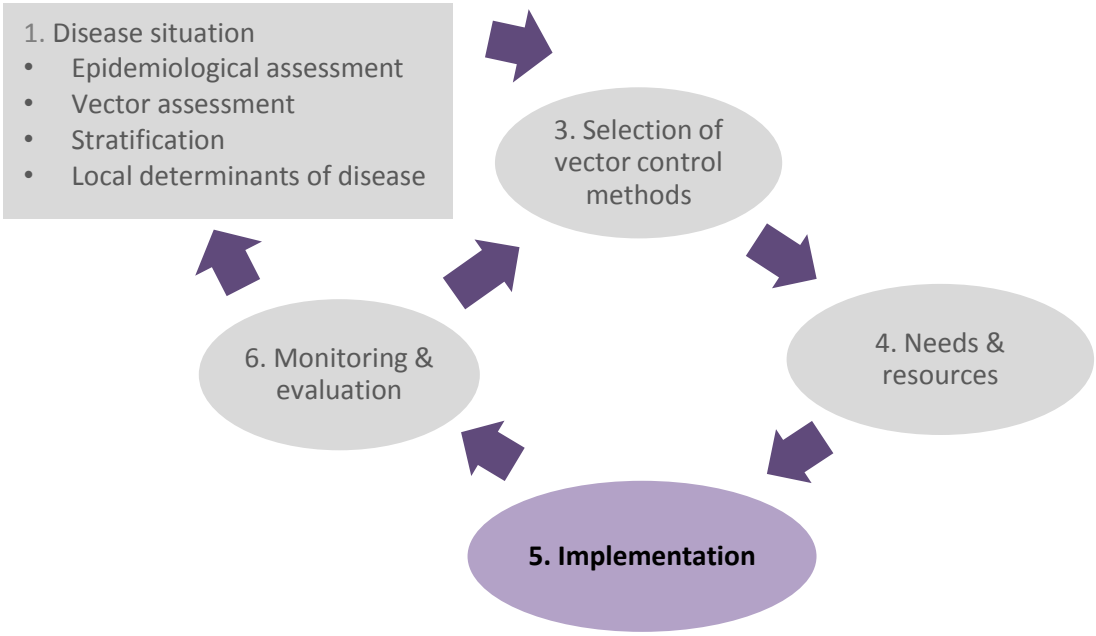
**KEY POINT**

When selecting the most appropriate vector control method or combination of methods it is important to consider their effectiveness, the local ecology and behaviour of the target species, resources available for implementation (human, financial and material), the cultural context in which control interventions are carried out, the feasibility of applying them in a timely manner, and the adequacy of coverage. Countries should use only those products recommended by WHOPES and meeting the quality control specifications and should conduct pre-shipment batch testing.

**CHAPTER SUMMARY**

- A wide range of vector control tools exist; which can be broadly classified into chemical-based and non-chemical based tools for control of either adult or immature forms of the vector.
- It is important to choose vector control tools on the basis of their efficacy primarily against epidemiological parameters (prevalence or incidence of infection/disease) although evidence of efficacy against the vector may be useful in some circumstances.
- Vector control tools may be effective against multiple diseases, for example IRS against malaria, lymphatic filariasis, dengue and leishmaniasis.
- A number of other factors should however, be taken into account when choosing vector control tools including vector characteristics such as insecticide resistance, human and environmental safety, affordability/cost effectiveness, acceptability and community participation and intervention implementation/delivery.
- Only WHOPES approved products should be used and pre-shipment batch testing should be performed.

# 5 Implementation strategy




In terms of implementation of IVM, you should consider:

1. **What** interventions you are going to deliver (Chapter 4)
2. **Where** these interventions are going to be implemented
3. **When** the interventions are going to be implemented
4. by **whom** are the interventions going to be delivered and **how**?

We attempt to cover these last four considerations in this Chapter.

## 5.1 Spatio-temporal targeting of IVM

### 5.1.1 Spatial targeting of IVM

IVM is about doing vector control is a smarter manner – making use of information on where vector borne pathogens and diseases are present in order to make better use of limited resources and target interventions to populations at highest risk. Therefore, it is very likely that specific IVM interventions will be targeted to specific geographic locations or on a finer scale, hotspots of disease. Since malaria is still the greatest killer in sub-Saharan Africa it is areas or populations with the highest burden of malaria morbidity or mortality that should be targeted first. However, against a backdrop of high LLIN coverage, IRS and LSM may for example be used in a more targeted manner for malaria and lymphatic filariasis control in rural areas. As well as more strategic use of resources, targeted IVM can be utilised for a number of other goals, including for outbreak response, elimination or tackling foci of high insecticide resistance.

#### 5.1.1.1 Targeting hotspots of disease either routinely or for elimination

Hotspots of disease may exist ordinarily as areas of higher transmission than surrounding areas or can appear when transmission has been reduced substantially so that only some patchy foci of

transmission remain. For example, although the main intervention for lymphatic filariasis is preventive chemotherapy, there may be some areas where repeated rounds of chemotherapy have failed to reduce transmission substantially and here it may be appropriate to implement vector control measures in addition to standard practice.

A targeted (proactive) IVM approach can be used to direct VBD control activities to small geographical areas where high transmission is expected based on historical data. See 3.2.2 and 9.5.1 for sources of information on disease incidence/prevalence in your country. This technique should be validated over time in your setting since it relies on hotspots of transmission being relatively constant over time. Although this method does not require timely and well-functioning case notification, it does require case locations to be geo-located and requires some expertise in identifying the 'most at risk populations' or hotspots. In a resource poor environment, geographic locations of cases can simply be plotted on a map to allow programme staff to visualise risk by geographic area. Community participation can be sought to identify breeding sites and other features such as health centres can be mapped. Programmes with greater expertise or links with research institutions can use more complex tools to identify clusters of cases in time and space using historic data. For example, the open-source software SaTScan (www.satscan.org) was used by the Malaria Control Programme in Mpumalanga Province to detect local malaria clusters [241] . This software scans the data with a series of circles looking for clusters of cases. Observed cases in a cluster are compared to the distribution of expected cases if spatial and temporal locations of all cases were independent. Identification of clusters assisted with the timely planning of public health activities and facilitated implementation of measures over and above standard practice in the identified hotspots. These included active case detection, early diagnosis and treatment of positive cases in the areas of the clusters, additional IRS, focal larviciding where breeding sites are few, fixed and findable and health promotion activities.

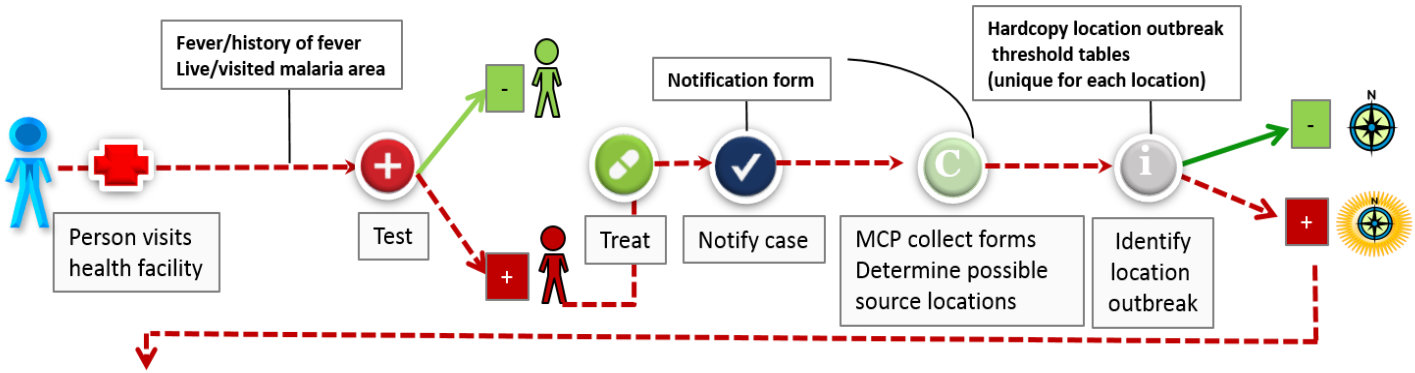
#### 5.1.1.2 Targeting outbreaks to prevent epidemics

Targeted IVM can be used where transmission is unstable with the potential for outbreaks or for epidemic response. This can be for example where transmission is spikey in space and time e.g. dengue or unstable malaria or where population movement brings non-immunes in contact with vector-borne pathogens e.g. refugee camps.

This approach requires a well-functioning surveillance and health information system with capacity for prompt recognition and reporting of an increase in cases and adequate resources allowing for an integrated response in a timely manner. Cases are reported at health facility level and this information is relayed back to the vector control programme (Figure 5.1). Often outreach teams go to the household of the case and conduct active case detection in the neighbourhood. Pre-determined thresholds specific to each health facility and/or village/area are used to determine when intervention is necessary. An example of the use of thresholds for outbreak detection in an unstable malaria transmission setting in South Africa is given in Box 5.1.

In areas at risk of unstable or epidemic malaria, we would recommend the use of IRS as an epidemic response tool as it has a rapid and reliable short term impact. In addition, detection and treatment of cases should be strengthened and LSM could be considered. LLINs are not recommended as an epidemic response tool, although if coverage is low in the epidemic area then gaps could be filled.

## Passive case detection & location outbreak/epidemic identification + response including IVM




**Response**

**MCP staff, health promotion staff, community members, entomologist and field technitians**

- **MCP staff**
  - prioritise outbreak locations for tracing cases
  - verify source locations
  - reactive case detection – test + treat, family and neighbours/special or mass survey
  - case mapping at household level
  - larval source management
  - IRS – if warranted e.g. low coverage
- **Entomologist**
  - vector surveillance, insecticide resistance monitoring
- **Health promotion staff**
  - IEC+BCC activities in effected communities
- **Community members**
  - community mobilization to identify vector breeding sites for management and mapping
  - in case of **epidemic**, distribute personal protection measures

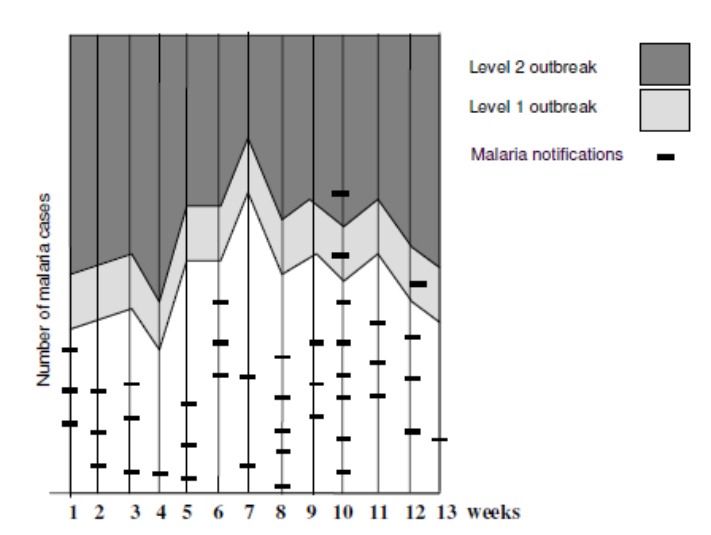
**Figure 5.1: Schematic illustrating use of IVM to target outbreaks**

**Box 5.1: Use of case thresholds to identify outbreaks and direct use of targeted IVM**

A relatively simple malaria outbreak identification system was evaluated in the epidemic prone rural area of Mpumalanga Province, South Africa, for timely identification of malaria outbreaks and guiding focal malaria control. The study used a threshold system of cases to trigger malaria control responses. A 3 tier system was used with thresholds at facility level, town/village level and Provincial Malaria Information System. Using 5 years of historical notification data, binomial thresholds were determined for each primary health care facility in the highest malaria risk area of Mpumalanga province. Wall charts were developed which showed outbreak thresholds (level 1 and level 2 outbreak) and allowed daily tallies of confirmed cases to be cumulatively charted against the weekly threshold.

If thresholds were exceeded at facility level (tier 1), then the staff notified the malaria control programme (MCP) who ensured that stocks of rapid diagnostic tests (RDTs) and treatments were sufficient to manage additional cases. The cases were followed up at household level to verify the likely source of infection. If thresholds were exceeded at town/village level (tier 2), then environmental assessment was conducted to identify breeding sites and larviciding was performed using an organophosphate. IRS coverage was also confirmed and if the number of cases was sufficiently high at town/village level for more than one successive week, additional IRS was considered.

In addition, an automated electronic outbreak identification system at town/village level (tier 2) was integrated into the Provincial Malaria Information System (tier 3) to ensure that unexpected increases in case notification were not missed. Automatic email alerts meant that managers at the MCP were able to conduct performance monitoring of tier 2 responses.




The threshold system was positively viewed by staff. 84% of health facilities reported outbreaks within 24 hours (n=95), 92% within 48 hours (n=104) and 100% within 72 hours (n=113). Appropriate response to all outbreaks was achieved within 24 hours (tier 1 n=113, tier 2 n=46). The binomial outbreak thresholds method performed well compared to other currently recommended outbreak thresholds such as those recommended by WHO (mean + 2 standard deviation) and CDC (cumulative sum).

This approach may not work for all diseases and settings. For example, countries prone to dengue epidemics often implement dengue control measures after the onset of an epidemic which is in most cases too late to have any impact.

#### 5.1.1.3 Targeting foci of insecticide resistance

Lastly, targeted IVM may be of use for management of foci of insecticide resistance. For example, reducing the source of mosquitoes by tackling breeding sites using LSM with environmental management of chemicals/biologicals to which there is no resistance in the vector population, introduction of LLINs with 2 active ingredients or rotation with expensive insecticides for IRS should be targeted to sites of high insecticide resistance if a blanket approach is not operationally or financially feasible.

### 5.1.2 Temporal targeting of IVM

Certain vectors can be responsible for transmitting more than one disease – for example *Anopheles gambiae* transmits both malaria and lymphatic filariasis and *Aedes albopictus* transmits both dengue and chikungunya. Also vectors of a number of VBDs increase during the rainy season. This offers opportunities for combining operations, thus increasing efficiency, especially where vectors can be controlled by the same or similar interventions. In general, vector populations should be targeted when they are at their lowest point and before they begin to rise.

#### 5.1.2.1 Malaria vector control

Malaria vector control should be continuous in order to supress transmission. In areas of moderate or intense seasonal malaria transmission LLINs or IRS need to be distributed before or at the start of the rainy season. LLINs are likely to remain effective for about 3 years but IRS will provide protection for around 6 months at most. This means that where transmission is perennial 2 rounds of spraying are needed each year. Again, if possible these spray operations should take place early on in the transmission season to provide maximum protection. If breeding sites can be located readily during the dry season these should be larvicided or the breeding sites removed by environmental management. Communities and the Ministry of Public works should also be engaged to remove waste and clear drains or build drains before the start of the rainy season. It does not make sense to larvicide during periods of exceptionally heavy rainfall since many larvae will be washed away and the larvicide diluted. Housing improvement should be done on a continuous basis and be seen as a long term investment for when control with LLINs and IRS stops.

#### 5.1.2.2 Lymphatic filariasis vector control

Where lymphatic filariasis is transmitted by *An. gambiae* then the same timings of interventions as for malaria control should be implemented – distribution of LLINs or IRS before the rainy season and targeting of breeding sites with LSM during the dry season to hit residual breeding sites or at the beginning of the rainy season. Polystyrene beads to target culicines in closed habitats should be put in place at any time except during heavy rains or flooding when balls can be washed away.

#### 5.1.2.3 Cutaneous and visceral leishmaniasis vector control

Interventions against sandflies with seasonal changes in abundance should be targeted at the time of year before adult vectors begin to rise [242]. Visceral leishmaniasis has a long incubation period and so interventions should be put in place where it has been ascertained that transmission is ongoing.

#### 5.1.2.4 Onchocerciasis vector control

Larvicides should be applied when the flow rate of rivers is lowest. At this time the vector population will be concentrated in specific areas and the cost of larviciding will be reduced.

#### 5.1.2.5 Dengue vector control

Peak transmission of dengue virus is often, but not always, associated with periods of high rainfall and high temperatures. Rainfall increases the number of breeding sites available for vectors and high temperatures increase the frequency with which vectors take blood meals and reduce the extrinsic incubation time.

With regards to dengue, some interventions should be in place continually in at risk areas as a preventive measure, for example LSM (e.g. container surveillance for *Ae. aegypti* and treatment or elimination of positive sites) and insecticide-treated materials. Other interventions should be reserved for epidemic control, for example adulticide spraying conducted in addition to the routine interventions.

#### 5.1.2.6 Human African trypanosomiasis vector control

Vector control interventions should be targeted when tsetse populations are at their lowest. In particular, during the dry season riverine tsetse will have retracted into dense forest where they are most easily attacked [243]. Often target deployments take place at the start of season in which the risk of floods and the degree of vegetation growth are minimal.

## 5.2 Delivery and implementation of IVM

Once a decision has been made on the types of vector control tools to roll-out, it is also important to consider **how** the intervention is going to be delivered or implemented and by **who**. Interventions can be implemented by vector control programmes, other sectors or community members. By whom and how the interventions are implemented may differ depending on the setting, resources available, groups or areas targeted by the intervention and aims of the programme (e.g. routine control, outbreak or epidemic control, elimination, mosquito abatement etc). As well as considering how the intervention will be implemented, control programmes should also consider supporting interventions to increase uptake and correct use of interventions and sustainability.

High coverage of vector control interventions is necessary in order to be effective against vector populations and pathogen transmission. This applies whether the aim is universal coverage of LLINs or targeted LSM for malaria control in a village where a substantial proportion of breeding sites will still need to be covered. A number of coverage targets have been set and internationally agreed (Table 5.1). Of particular importance is WHO guidance on achieving universal coverage of LLINs for populations at risk of malaria, which recommends using a combination of delivery methods - mass free distributions and continuous distributions through multiple channels, in particular antenatal and

immunisation services [35]. Programmes should try to achieve these where possible and this should be tracked and documented as an indicator in your monitoring and evaluation plan.

**Table 5.1: Target coverage levels of interventions**

| Disease | Intervention | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | LLINs | Insecticide- treated curtains / screening | IRS | LSM | Indoor or ULV spray | Molluscicides | Traps or targets | Insecticide - treated cattle |
| Malaria | Universal coverage [35] | | >80% [244] | As many breeding sites as possible | | | | |
| Lymphatic filariasis | (Rural transmission) Universal coverage*[35] | | | | | | | |
| Dengue | | >70% [111] | | | | | | |
| Leishmaniasis | Universal coverage [35] | | >80% | | | | | |
| HAT | | | | | | | *Tbg* 50 metres apart [152] *Tbr* 4 baits per sq. km. [151] | |
| Onchocerciasis | | | | As many breeding sites as possible | | | | |
| Rift valley fever | | | | | | | | Treatment of all domestic livestock |
| Schistosomiasis | | | | | | As many water bodies as possible | | |
| Universal coverage is defined as one LLIN per two persons, *most likely to be effective at lower coverage [245], *Tbg = Trypanosoma brucei gambiense, Tbr = Trypanosoma brucei rhodesiense* | | | | | | | | |

### 5.2.1 Implementation by vector control programmes

Interventions that require strong logistical or technical knowledge such as aerial spraying for tsetse control or indoor ULV in a dengue epidemic situation will need to be delivered by vector control programmes. VBD control programmes may be able to share costs and resources in the delivery of interventions. For example, the malaria control programme should work in tandem with the lymphatic filariasis control programme to deliver LLINs to areas where both diseases are endemic.

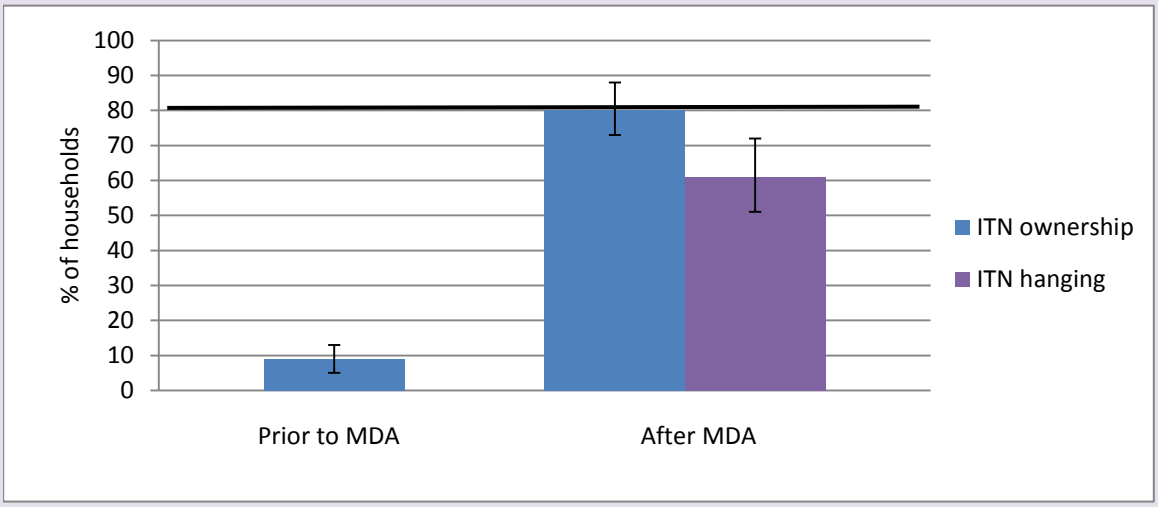
Cost savings and other benefits are also achievable when interventions are delivered in tandem, for example the same vector control team performing LSM and IRS, or co-delivery of mass drug administration and LLINs. An example of co-delivery of interventions is integration of LLIN distribution with mass drug administration (MDA) for lymphatic filariasis and onchocerciasis in central Nigeria is given in Box 5.2. Although the number of LLINs distributed in this example is relatively low (38,600) it does show the feasibility of this approach. Integration of activities not only saves resources but can have synergistic effects on pathogen transmission. For example, integration of active screening for human African trypanosomiasis and vector control in the form of tiny targets had a greater impact on disease prevelance than active screening alone [159].

**Box 5.2: Successful integration of LLIN distribution with MDA for lymphatic filariasis and onchocerciasis in central Nigeria** (adapted from [246])

In Africa anopheline mosquitoes transmit malaria and lymphatic filariasis (LF) and long-lasting insecticidal nets (LLINs) are likely to reduce transmission of both diseases. Provision of LLINs, in particular to target groups such as children aged under 5 years old and pregnant women is a major goal but use of LLINs remains relatively low due to a number of factors. This study attempted to deliver LLINs alongside mass drug administration (MDA) for LF and onchocerciasis.

LLIN distribution was integrated with the 2004 LF/onchocerciasis MDA programme in central Nigeria. Community volunteers distributed 38,600 LLINs, while simultaneously treating 150,800 persons with ivermectin/albendazole (compared with 135,600 in 2003). Changes in LLIN coverage and use were assessed with a 30-cluster survey. Among surveyed households containing children aged under 5 years/pregnant women, 80% (95% CI, 72-87%) owned > or = 1 insecticide-treated bed net, a 9-fold increase from 2003.

Graph shows percentage LLIN ownership and use by households with vulnerable sleeping spaces prior to the MDA (2003) and after MDA (2004).




Linkage of LLIN distribution with MDA resulted in substantial improvement in LLIN ownership and usage, without adversely affecting MDA coverage. Such integration allowed 2 programs to share resources while realizing mutual benefit, and is one model for rapidly improving insecticide-treated bed net coverage objectives.

## 5.3 Involving the non-health sector in IVM

The health sector has conventionally been responsible for vector control, and interventions that require strong logistic support, such as IRS, usually require the specialist skills and capacity of the health sector. However, implementation and maintenance of each type of intervention need not necessarily be carried out by the Government's health sector. Government offices other than health and other organisations can and should, however, share the responsibility for certain vector control methods or certain areas. Other partners, such as non-governmental organisations (NGOs), communities, schools, the private sector and public sectors such as agriculture, construction and local government also have important roles in planning and implementing vector control and personal protection. Strong policy support and advocacy from the IVM Steering Committee (ISC) is required for intersectoral collaboration. As well as reducing VBDs, interventions in other sectors can also help to improve wellbeing. For example, drainage of wetland areas can reduce biting mosquito nuisance and installation of piped water for dengue control rather than storing water in the home is beneficial for women and children. The ISC should build an awareness of the important contribution of the non-health sector to VBD and VBD control – for example, by highlighting the role of dam construction and agricultural irrigation schemes in creating suitable vector habitats.

Examples of interventions against VBD that can be initiated outside the health sector are outlined in Table 5.2. For example LLINs can be distributed by NGOs. Drainage schemes to reduce mosquito breeding may be done outside the health sector, for example, by the Ministry of Public Works. Wetlands can be dried by planting eucalyptus trees, an activity that would fall under the Department of Forestry, or made unfavourable for the aquatic forms of *An. gambiae* by regenerating papyrus swamps which would provide shaded areas unsuitable for this mosquito. Environmental management in agricultural areas, irrigation systems, construction sites, waterways and peri-urban areas could be administered by the agriculture, irrigation and environment sectors and local government (Figure 5.2). Schools and work places may be particularly important for daytime biting vectors (e.g. dengue) and so should be involved in vector control activities. Box 5.3 gives a practical example of the involvement of the Ministry of Education in health promotion to primary school children regarding

**Figure 5.2: Environmental management through drain clearing to reduce breeding sites** (photo courtesy of S. Lindsay)

dengue. Malaria control in Khartoum through the Khartoum Malaria Free Initiative (MFI) provides a good example of the involvement of a number of sectors and community participation in vector control (Box 5.4). Strong political will and effective intersectoral collaboration has been integral to the success and sustainability of the MFI. While interventions can be initiated and implemented outside the health sectors, these activities should be overseen and coordinated by the IVM Focal Person at regional or district level.

**Table 5.2: Interventions against VBD that could be initiated outside the health sector**

| Interventions | Ministries/organisations involved in implementation |
|---|---|
| Health education & promotion | Schools, Ministry of Education, work places, the media (TV, radio, internet), drama groups, NGOs, religious and community groups |
| LLINs / IRS / insecticide treated sheeting or tents | NGOs, UN, VBD control programmes, private sector, ministry of tourism, womens groups, |
| House improvements and screening | Ministry of Housing, NGOs, community members |
| Drainage | Department of Public Works, local government |
| Drain clearance | Youth groups who collect rubbish to sell, community members (Figure 5.3) |
| Drying out of breeding sites | Department of Forestry, local government, community groups |
| Swampland restoration | Department of the Environment |
| Removal of obsolete concrete water storage containers (used for building) | Department of Public Works, contractor, local government |
| Filling & levelling | Department of Public Works, local government |
| Maintenance of irrigation channels or flushing | Farmers, Ministry of Agriculture, irrigation authority |
| Removal of vegetation from edges of water bodies | Farmers, community members |
| Intermittent irrigation | Farmers, Ministry of Agriculture, irrigation authority |
| Improved housing | NGOs, microfinance initiatives, Department of Housing |
| Larval or snail surveys / application of larvicides or molluscicides | Schools, community groups, municipal corporations, public health staff, farmers |
| Improvement of environmental sanitation | NGOs, Department of Public Works, local government |
| Water supply and sanitation | Ministry of water resources, Ministry of environment and sanitation, NGOs |
| Social and environmental responsibility e.g., tyre disposal | Private companies |
| Solid waste and container disposal | Garbage collectors, local government, youth groups, industry |
| Insecticide-treated cattle | Farmers, ranch owners, veterinary services |
| Topical insecticide on dogs or insecticide treated collars | Dog owners, veterinary services, local municipalities |
| Culling of reservoir animals | Community members, veterinary services, local municipalities |
| Destruction of habitats of rodent reservoirs of leishmaniasis | Farmers, community members, local municipalities |

**Figure 5.3: Drains are excellent breeding sites for culicines and should be cleaned , treated or made inaccessible to vectors** (photo courtesy of S. Lindsay)

**Box 5.3: Primary school education as a strategy for dengue control [247]**

A study was carried out in the city of Botucatu, São Paulo (Brazil) to see whether education of primary school children could be used as a strategy for dengue control, with the aim of empowering these children to be 'agents of change' in their community. An educational intervention was put in place consisting of an explanation of the biology and development of the mosquito, information on the disease, virus, transmission and prevention. In addition, a video on dengue was shown, debates were held, children observed the life cycle of the mosquito under a microscope, and children completed exercises in an exercise book.

The effect of the teaching intervention was measured by giving the children quizzes before and after the 2 week programme of lessons. Children who had participated in the lessons scored better on the quiz post-intervention, with a better knowledge of the life cycle, transmission of dengue by adult mosquitoes, breeding sites (including identifying breeding sites in their homes), control measures and disease symptoms.

While the study is not able to show whether the educational intervention had an impact on action being taken against the vector, some studies have shown that such interventions can favour a change in the behaviour of the population resulting in a decline in breeding sites.

**Box 5.4: Malaria control in Khartoum [248-250]**

The Khartoum Malaria Free Initiative (MFI) was launched in 2002 by the State and Federal Ministry of Health. This was in response to a high malaria burden – in the 1980s and 1990s malaria was the major cause of outpatient attendances, admissions and deaths in Khartoum. Since the MFI was launched total malaria deaths have declined by almost 75% from 1,070 in 1999 to 274 in 2004 and parasite prevalence has declined from 0·78% to 0·04% (1995-2008).

The MFI comprises three components (diagnosis and treatment, prevention and epidemic surveillance). The mainstay of prevention is control of the primary malaria vector *Anopheles arabiensis,* which breeds largely in irrigation canals, pools created from broken water pipes, water basins and storage tanks. New agricultural schemes and new construction sites continually create more breeding sites. A number of vector control methods have been put in place:

- Larviciding and environmental management is undertaken by the MFI which employs 14 trained medical entomologists, 60 public health officers, 180 sanitary overseers, 360 assistant sanitary overseers and 1170 spraying men.
- Removal of water basins and storage tanks is enforceable by law.
- Regular drying of irrigated fields is compulsory in Government and private irrigation schemes and is supported by the Farmers Union and the Ministry of Agriculture. In 2011, 98% of irrigation schemes were dried for at least 24 hours.
- In conjunction with the Ministries of Irrigation and Agriculture, any leakages from irrigation canals are repaired and vegetation around canals is cleared.
- The Ministry of Health collaborates with the Public Works Department (PWD) to repair or replace broken water pipes. The MFI is responsible for surveillance, reporting and transportation while the PWD provides engineers and equipment. By 2004, just under 4km of water pipes had been replaced and over 6km repaired.
- The MFI has strong community support which is generated through the distribution of information leaflets, regular radio broadcasts and television coverage, health education in schools in collaboration with the Ministry of Education, the organisation of an annual 'Khartoum State Malaria Day', public meetings and the establishment of malaria control committees and societies.
- 405 schools and 287,000 pupils are involved in mosquito larval control activities.
- IRS and LLIN distributions are not carried out in Khartoum but LLINs are exempt from import tax to encourage sales in the private sector.
- Malaria case management is strengthened through training on malaria diagnosis and case management and provision of antimalarial drugs through the 'revolving drugs fund'.

The MFI has strong political support at both State and Federal Level and there is close collaboration between the State and Federal Ministry of Health and other Ministries including Ministries of Health, Education, Public Works & Agriculture. Involvement of other sectors has also helped to keep costs low – the total annual cost of the programme (which targets a total population of 2 million in urban areas, 3 million in peri-urban areas and 0.6 million in rural areas) is US$600,000 or around US$0·10 per person protected per year.

### 5.3.1 Community participation in IVM

All vector control activities need community support and participation so considerable effort must go into engaging with local communities. Communities can be actively involved in some vector control activities, in particular environmental management. For example, community participation can be crucial for source reduction. We also provide examples of community participation for dengue control in South America (Box 5.5) and community-based environmental management for urban malaria control in Uganda (Box 5.6). Dengue in Africa is an emerging problem and so it is useful to learn from established programmes in South America that incorporate strong elements of community empowerment and intersectoral collaboration. We also present the example of Farmer Field Schools whereby standard curricula aimed at improving crop yields and reducing pests are tailored to include malaria control and farmers are empowered to design and evaluate their own control experiments (Box 5.7). Box 5.8 gives an example of community-based trapping for tsetse control in South Sudan which showed benefits against disease but also community empowerment. An excellent example of capacity building of community-based Health Extension Workers (HEW) to implement IRS in Ethiopia is given in Box 7.3.

**Box 5.5: Community involvement in dengue control** [251, 252]

Community-based strategies for dengue control incorporating intersectoral collaboration, health education, environmental management and community participation have been tested in a number of settings in South America.

**'Clean Backyard' strategy - Mexico**

In Mexico, the *Patio Limpio* or 'clean backyard' strategy has been implemented. The idea of this strategy is to train community members to identify and eliminate breeding sites, emphasising the importance of each household in contributing to fight against dengue and the common aim of dengue free community. During the implementation phase a local assembly is held with community members where the concept is explained. Community leaders known as 'block activators' are identified from each block and receive training. The 'block activators' then train the community members from their block on how to identify and eliminate breeding sites and to help them understand the benefits of keeping the household clean. The 'block activators' perform a monthly assessment of area the under their control and attend community assemblies. The results of surveillance activities are fed back to the 'block activators' and recommendations made when expected outcomes are not met. The effect of the 'clean backyard' strategy on mosquito breeding sites in Guerrero, a state in south Mexico was assessed over one year (2007). As well as training of the 'block activators' and community mobilisation, the communication strategy included displaying 18 signboards and 130 posters, three daily loudspeaker transmissions in areas such as shopping centres and markets throughout the community, and distributing pamphlets to every household visited by block activators. More than 1000 block activators were identified and trained, with an average of approximately 15 households managed by each activator. From a sample of 5477 backyards, approximately 54% (2918) were designated as 'clean' and free of breeding sites. Further analysis revealed that households not visited and assessed by a block activator, had a 2.4-times higher risk of developing dengue, compared to those who had been trained and supervised by an activator. In addition, 80% of trained households were able to identify a breeding site and mosquito larvae at the 3-month follow-up visit. Sustaining the behaviour change was however, identified as a problem with the following up survey at the one year timepoint indicating that only 30% of trained households had a clean backyard and were aware of the risks associated with breeding sites in their households.

**Action research to stimulate community participation – Santiago de Cuba, Cuba**

A quasi-experimental study was conducted in Santiago de Cuba, Cuba to assess the effect of an intervention to increase stimulate community participation in dengue control on entomological parameters. The intervention aimed to mobilise the community for all stages of *A. aegypti* control, from problem identification, planning, implementation and evaluation. The intervention was implemented according to the following steps:

1. Formative research using social research methods (e.g. KAP surveys, focus group discussions, behavioural observations) to inform the design of the intervention.
2. Community Working Groups (CWG) were implemented comprising 10-20 members including formal and informal leaders, public health workers from the governmental vector control programme and the doctors and nurses of the neighbourhoods' family medicine practices. CWG became responsible for co-ordination of intersectoral action at the local level and were asked to rethink ways of involving the community.
3. CWGs held meetings with the community to identify local needs and priorities for dengue control.
4. Action plans were developed and implemented based on the priorities of the vector control teams and community members.

A social communication strategy using interpersonal communication in face-to-face encounters and community meetings, as well as local mass media was used to mobilise the community and promote behaviour change. Behaviour change was promoted with respect to LSM and environmental management – for example covering water storage containers, removing containers that may fill with water and not removing temephos from water storage containers. The CWG secured provision of materials for repair of water containers and construction of covers free of charge from the local government. The CWG also worked with government intersectoral committees to negotiate action on larger projects including repairing broken water pipes and sealing the foundations of some buildings that served as breeding sites. For the repair of water storage containers and the construction of covers, they secured cement, wood and nylon, which was provided free of charge to the community by the local government. Additionally, risk surveillance was set up and consequently conducted by the community through the introduction of tools for mapping intradomiciliary and extradomiciliary environmental risks.

After implementation of the intervention, household risk behaviour was reduced - uncovered water storage containers decreased from 49% to 3% and removing larvicide from water containers dropped from 46% to 1% between 2000 and 2002. There was also a reduction in entomological parameters with a reduction in the absolute number of positive container by 75% and a significant reduction from 1.23% to 0.35% in the house index.

In conclusion, local CWG were able to engage community members and local government to resolve problems of mutual concern, although the project was time-limited and sustainability remains unclear.

**Box 5.6: Community-based environmental management for urban malaria control in Uganda (adapted from [253])**

Environmental management for vector control involves either habitat modification or manipulation with a view to preventing or minimising vector propagation. A study was conducted to assess the strengths and weaknesses of a community-based environmental management for malaria control in 2 Ugandan cities: Kampala and Jinja. Both cities provide ample breeding sites for malaria vectors. In Kampala, high rainfall results in rapid run off of large volumes of water that collects in valley bottoms throughout the city and Jinja, being located next to Lake Victoria has large areas of swamp.

Initially, entomological and clinical surveys were conducted to determine the level of transmission and intensity of infection in different areas of the city. Four sites were chosen – in Kampala sampling was done in small valleys where flooded brick pits (where clay is collected for brick making) and in Jinja sampling sites were close to farmland or swamps.

In partnership with the local health authorities, community mobilisation by way of house visits and meetings was used to inform and engage communities (e.g. youth and womens groups, brickmakers). Based on the survey findings, control options were identified and a participatory approach was used to develop community action plans specific to the vector ecology and setting in each site. Communities selected packages of interventions they felt were appropriate to their setting. For example, in Kampala communities decided to fill in puddles, drain the brick pits and introduce larvivorous fish into larger water bodies. In the second year of the study, the communities implemented their action plans with support from local health authorities, the study

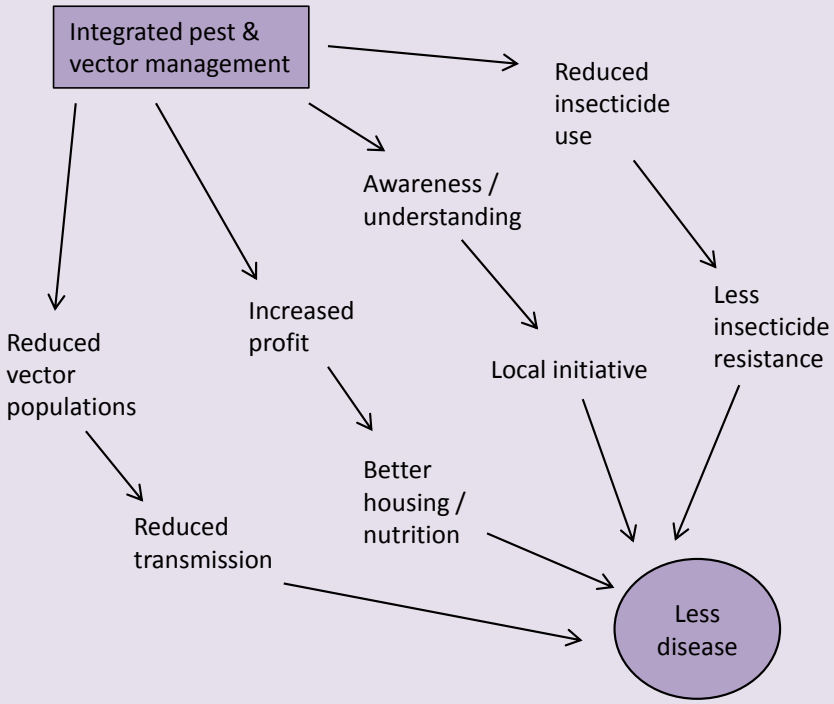
**Box 5.7: Farmer field schools – involving rural communities in malaria control (Figure adapted from [254])**

Agricultural environments can provide excellent breeding sites for malaria vectors with clear, temporary water bodies coinciding with the time of crop cultivation and a ready supply of human and animal hosts for feeding in close proximity. Widespread use of insecticides for agriculture is likely contributing to resistance to public health insecticides such as those used for malaria control.

Malaria control has been integrated into a complementary intervention in rural development known as Farmer Field School (FFS) on Integrated Pest Management (IPM). The FFS is a form of education that uses the concept of 'learning based on experience' to build farmers expertise. During the crop cycle, a group of 15-30 neighbouring farmers meet weekly to make field observations and discuss together regarding crop pests, beneficial organisms, plants, soil and environmental conditions. The farmers are encouraged to brainstorm and design experiments (e.g. "what if, instead of spraying, we drain the water to control planthoppers in rice"), which are then evaluated the following week. These weekly completed learning cycles result in strengthened skills and increased confidence of farmers and group dynamics and communication exercises are conducted to strengthen group cohesion, maintain motivation and help participants to develop organizational skills. A review of FFS experiences indicated positive outcomes including drastic reductions in agro-pesticide use, economic benefits and empowerment effects.

In malarious areas the IPM curriculum is amended to include the ecology and control of malaria, and to involve farmers and others in the control of malaria in their environment. This combined strategy has been labelled Integrated Pest and Vector Management (IPVM). The best documented pilot of this approach is from Sri Lanka where the IPVM curriculum has recently been developed for the wetland rice ecosystem. Learning activities include encouraging farmers to identify malaria breeding habitats by sampling using dippers, study the mosquito lifecycle by rearing young larvae in water jars covered with mesh and sample and identify adults of the 3 main mosquito genera at different times and habitats to gain an understanding of disease vector activity. Farmers also assess the effects of agricultural methods to suppress mosquito breeding (e.g. alternate wet-dry irrigation of study field plots, land levelling at planting) and draw maps of the village environment with water bodies, crops, houses, etc. to facilitate planning for coordinated action on environmental management.

There are 4 different mechanisms by which IPVM FFS can impact on malaria disease i) reduced pesticide use reduces selection pressure on malaria mosquitoes, ii) increased awareness and understanding about malaria on personal protection measures and treatment-seeking behaviour, iii) effect of increased profits from agriculture on housing, nutrition, treatment access etc and iv) the effect of environmental management on vector breeding and thus on the transmission of disease.




Although this example is from Sri Lanka, the FFS concept is established in sub-Saharan Africa (SSA) for increasing agricultural productivity and so the curricula could be adapted to different ecosystems where malaria and other VBD are present.

**Box 5.8: Community-based tsetse trapping in South Sudan [255]**

South Sudan experienced a resurgence of human African trypanosomiasis in the 1990's. Seroprevalence surveys organised by Cooperative for Assistance and Relief Everywhere (CARE), the International Medical Corps, and the US Centers for Disease Control and Prevention (CDC) identified foci of high transmission. In one of these foci (Tambura County) a community-based tsetse trapping project was introduced alongside mass screening and treatment. Villages participated in making, setting and maintaining more than 3000 pyramidal traps which were placed near places of increased human-vector contact including near village farm plots, water sources, and areas in which people gathered firewood.

A train-the-trainer approach was used. National health officials were trained on tsetse fly biology and control methods. Community mobilisation was carried out before community selection of 350 volunteers. Volunteers were mainly traditional birth attendants. County health officials worked with volunteers to prepare village maps marked with key sites for trap placement. Volunteers were trained to collect flies from the traps and received bicycles to enable them to collect and submit caught flies to county health officials. County officials, in collaboration with CARE monitored fly density over time.

Fly densities caught in traps dropped from 25 per trap per week at the beginning of the project to fewer than 3 flies per trap per week. Importantly, seroprevalence fell from 9% to 2% between 1997 and 1999. Another benefit of the intervention being community-based was that the community members learnt about the causes and prevention of sleeping sickness and were more willing to participate in screening and seek treatment.

### 5.3.2 Involving the private sector in IVM

In some areas it may also be beneficial to involve the private sector in IVM, whether this is the tourism sector, employer-based VBD control programmes or social responsibility projects. The tourism sector in particular should be encouraged to invest in VBD control since a reduction in VBD in an area will have a positive impact on visitor numbers. For example, hotels may have a role in introduction of new dengue virus strains and so should be encouraged to practice source reduction around the premises and provide bednets to prevent the establishment of new strains in the community. Businesses such as mines or plantations may provide employer-based VBD control programmes run in collaboration with local partners or as a complement to national scale-up activities, such as the example of Anglo Gold Ashanti (Box 5.9). Ranches in human African trypanosomiasis endemic areas could be encouraged to implement control measures such as insecticide-treated cattle [160]. There are economic and social benefits of businesses investing in VBD control and several examples exist showing the cost effectiveness of employer-based malaria control programme [256]. Companies can be encouraged to implement social responsibility projects in communities, such as the work of Marathon Oil supporting the National Malaria Control Programme (NMCP) in Bioko Island, Equatorial Guinea which has helped to reduce the malaria burden [257]. Alternatively, vector control programmes can exploit the leveraging effect of private companies, for example to secure funding from external donors, jump start intervention scale-up or build on existing NMCP operations by providing financial or human resources, expertise and

advocacy. A management guide to help any company or organization operating in malaria-endemic regions of Africa develop an effective malaria control program is available [258].

**KEY POINT**

Vector control programmes should consider involving the private sector in VBD control activities. There are economic (reduced direct and indirect costs of VBD) and social (build reputation of company for social responsibility and good corporate citizenship) benefits of businesses investing in VBD control.

**Box 5.9: Business investment in malaria control – Anglo Gold Ashanti in Ghana (adapted from [256])**

The gold mining company Anglo Gold Ashanti are based in Obuasi, Ghana, a malaria endemic area. In 2004, malaria accounted for 22% of all deaths in the community and the local hospital and clinics saw as many as 12 000 confirmed and unconfirmed cases of malaria per month. The cost to the company in providing malaria care to workers and their dependants was also massive, with approximately US$ 55 000 spent each month on treatment alone.

To address this problem, in 2005 the company decided to implement an integrated malaria control programme focusing on mineworker housing and infrastructure, as well as surrounding villages. Importantly, the programme was developed and conducted in partnership with the Ghana Health Service, Ghana National Malaria Control Programme and the Obuasi Municipal Assembly. It also had to be aligned closely to Ghana's National Malaria Plan. The programme consisted of vector control (LLINs, IRS and larviciding) and diagnosis and treatment of confirmed cases with artemisinin-combination therapies (ACTs), alongside information, education and communication campaigns.

After implementation of the programme there was a drop in the number of malaria cases reported at the mine hospital from 6600 cases per month in 2005 to 1150 cases per month in 2009. Absenteeism due to malaria was also reduced – average monthly lost days of work due to malaria fell from 6983 in 2005 to 282 in 2009. There was also a reduction in average monthly medication costs to the company from US$ 55,000 in 2005 to US$ 9,800 in 2009.

#### 5.3.2.1 Supporting interventions

Once vector control tools have been selected, it is important to consider which supporting interventions need to be rolled out. Communities need to be informed about diseases, their transmission and control methods. Supporting interventions can play a major role in encouraging correct use and care of interventions such as LLINs and IRS. For example, LLIN distribution campaigns may be accompanied by distribution of Behaviour Change Communication (BCC) messages using radio spots, posters and leaflets, or may be followed up by hang-up campaigns where community volunteers visit households to hang up nets and distribute messages about

benefits and use of LLINs. The use of theatre, songs and dance to inform communities about diseases and control methods and encourage behaviour change is described in two examples in Box 5.10. Text-messaging could also be used to distribute messages and encourage behaviour change [259]. For example, text message reminders of intermittent preventive treatment of malaria in pregnancy (IPTp) visits could be combined with messages on LLIN use for pregnant women [260].

**Box 5.10: The use of folk theatre to encourage behaviour change for malaria control [261, 262]**

*Kalajatha* is a popular, traditional art form of folk theatre in India. It is an effective medium of mass communication in the Indian sub-continent, especially in rural areas where due to the low literacy rate many conventional methods such as posters, pamphlets, hoardings and electronic media have limited effects.

In 2001 *Kalajatha* was used disseminate health education messages for bio-environmental control of malaria in Tumkur District, Karnataka State, south India. The National Institute of Malaria Research (NIMR) and Community Health Cell (CHC), Bangalore jointly initiated the programme and an inter-sectoral co-ordination committee was formed for coordination purposes. Support of local government was obtained. The district health committee headed by the District Commissioner approved the proposal of the Kalajatha programme. NIMR and CHC, the Departments of Health, Education, Child and Women's Welfare, Rural Development and Panchayat Raj, Tumkur Science Forum, local political and religious leaders actively participated in this programme.

Thirty local artists were selected and scriptwriter wrote songs, drama s and musical dramas. Topics covered by the theatre included signs and symptoms of sickness, treatment, health facilities, transmission, role of anopheles mosquitoes and breeding sites of mosquito vectors. The theatre pieces also covered malaria control strategies focusing especially on larvivorous fish (*Poecilia reticulata* and *Gambusia affinis*) and environmental management. Events were publicised widely and community consent was given for the events to take place by community leaders. Local media covered the events also and helped in spreading the key messages.

The impact of the folk theatre events was assessed after 2 months by comparing the knowledge of *Kalajatha* attendees versus those that were not exposed using semi-structured questionnaires. *Kalajatha* attendees had a significant increase in knowledge about malaria, its symptoms, transmission and control methods. They could easily associate clean water with anopheline breeding and the role of larvivorous fish in malaria control. The year after the Kalajatha events were held the community participated in releasing larvivorous fish which resulted in a reduction in malaria incidence.

An example of the use of folk theatre for behaviour change communication in sub-Saharan Africa is that of Netos de Bandim. This is a youth dance group based in Guinea-Bissau which designs community education campaigns using dance, theatre, music, poetry and community dialogues to convey public education messages. They have conducted campaigns focusing on HIV/AIDS, cholera and malaria.

In 2011 Netos de Bandim worked with UNICEF to educate over 2000 families in 10 Bissau neighbourhoods about malaria prevention and protection. The leaders of Netos de Bandim learn about the issues they will be working on and teach the youth members of the dance group about it. The youth then work in groups or individually to come up with role-plays, songs and poetry to help convey the message. The dance group deliver these behaviour change messages by organising large block parties in Bissau neighbourhoods which drew large crowds due to the big reputation and following of Netos de Bandim. Once the young people of the community see the plays they mimic them and reproduce them daily in their communities as a game. This helps to reinforce the messages expressed.

The project enabled over 100 young people of the dance group to learn about malaria and to exercise leadership through teaching their community about malaria prevention. The approach also preserves and encourages appreciation for various cultural dance forms and other cultural traditions, which helps to promote ethnic tolerance and social cohesion.

### 5.3.3 Cross-border initiatives for vector control

In some situations it may be worth considering cross-border initiatives for VBD control. There are several examples of this including the Trans-Kunene Malaria Initiative (TKMI) in the Trans-Kunene region comprised of Cunene and Namibe provinces in Angola and Kunene, Ohangwena, Omusati regions in Namibia. A good example for malaria control is provided by the Lubombo Spatial

Development Initiative (LSDI) cross-border collaboration for malaria control between Swaziland, Mozambique and South Africa is outlined in Box 5.11. In the past, cross-border initiatives have also been implemented for control of human African trypanosomiasis. For example, the Regional Tsetse and Trypanosomiasis Control Programme (RTTCP) between Zimbabwe, Mozambique, Malawi and Zambia in the 1980's [263]and Farming in Tsetse Controlled Areas (FITCA) between Uganda, Ethiopia, Kenya and Tanzania in the late-1990's to early 2000's [264]. Where areas of tsetse infestation cross country boundaries, coordinated effort is required to control tsetse successfully and prevent re-invasion.

**Box 5.11: Lubombo Spatial Development Initiative (LSDI) for malaria control [265, 266]**

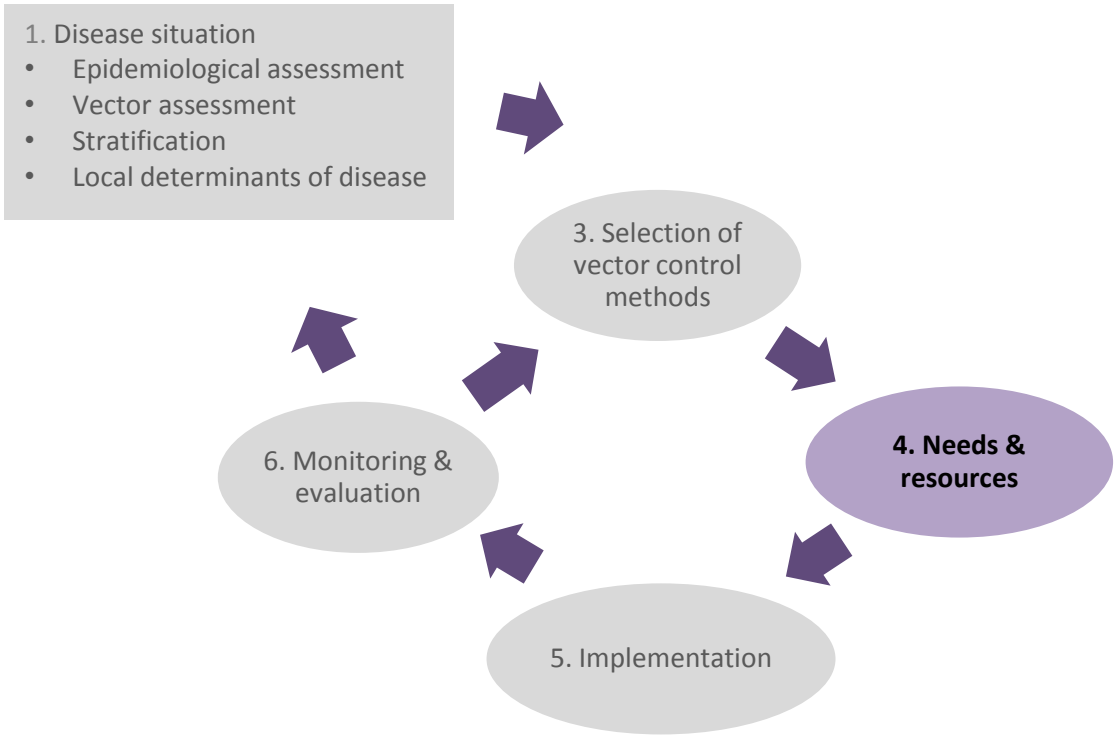
The Lubombo Spatial Development Initiative (LSDI) is a tri-lateral development programme between the governments of Mozambique, Swaziland and South Africa which includes malaria control as a key component. The Lubombo region comprises of eastern Swaziland, southern Mozambique (Maputo province), and northeastern KwaZulu-Natal. The LDSI was established in 1999 with the signing of a protocol of understanding by the heads of state of the 3 countries who set up a tri-national malaria control programme (MCP) coordinated by the Malaria Research Unit (MRU) of the South African Medical Research Council (MRC). The tri-national MCP met quarterly to address any issues. Comparatively strong control programmes in Swaziland and South Africa meant that the programme focused on extending effective control into southern Mozambique which was an important reservoir of transmission and point source for imported cases given the substantial levels of population movement across the region. The programme is 2-pronged: prompt diagnosis and treatment of malaria cases and vector control, mainly using IRS. Vector control using IRS was rolled out into southern Mozambique in a staged fashion from between 2000 and 2004. Impact was monitored using annual cross-sectional surveys to assess prevalence of P. falciparum infection, entomological monitoring and malaria case notification in neighbouring Swaziland and South Africa. Significant reductions in *Plasmodium falciparum* prevalence were reported in southern Mozambique, along with reductions in notified cases in Swaziland and South Africa over the same time period. The project was so successful that it was expanded in Gaza Province in Mozambique which borders on Mpumalanga and Limpopo provinces in South Africa. This brought the contiguous area under malaria control by the LSDI malaria control programme to more than 200,000 $km^2$.

Capacity and infrastructure development played a large role in the programme. For example, the LSDI malaria control offices set up in close collaboration with provincial health departments in Mozambique. Local staff were trained in order to be able to coordinate and manage the programmes with skills transfer and supervision from experts in Swaziland and South Africa. Annual training camps for IRS operators were held before the onset of each spraying round to ensure sprayers were competent and maintain consistency across areas. Healthcare providers were trained in malaria diagnosis and treatment and monitoring and evaluation. A comprehensive malaria information system with a spatial component was developed which facilitated planning and monitoring of spraying by providing managers with information on malaria cases and vector control activities. The success of the program in reducing malaria transmission throughout the target area provides a strong argument for investment in regional malaria control.

**CHAPTER SUMMARY**

- In terms of IVM implementation, you should consider **what**, **where**, **when** and by **who** interventions will be implemented and **how**?
- Vector control interventions can be targeted in space and time – this is usually done against a background of interventions such as LLINs which are implemented on a continuous basis.
- By targeting vector control interventions in space and time, we can use resources more strategically under routine conditions or target areas for epidemic control or foci of insecticide resistance.
- The timing of implementation should also be considered in order to maximise the effects of the intervention on vectors and disease.
- Interventions that require strong logistical support and technical knowledge are generally implemented by vector control programmes.
- Co-delivery of interventions can have a number of benefits, including resource savings.
- IVM should involve other sectors where possible in vector control. Community participation and the skills and resources of private sector companies should be harnessed.
- Regional partnerships such as the Lubombo Spatial Development Initiative can be beneficial for VBD control.

# 6 Needs and Resources




When the locally appropriate vector control methods have been selected, an inventory should be made of the **financial resources, human resources and infrastructure (research/training/technical and operational facilities)** available for vector borne disease (VBD) control at national, provincial or district level. As mentioned in Chapter 2, WHO materials on vector control needs assessment and the IVM curriculum may be helpful in assessing country capacities and resources [11, 267]. The organizational structures in which the resources could be used should also be assessed. This is likely to vary according to the country, province and district but we provide here some suggestions to help you plan.

The inventory of resources and organizational structures requires the participation of local stakeholders. Possible links and collaboration with other local programmes or government services should be discussed, so that activities are coordinated in order to ensure consistency and avoid duplication. The potential resources include those received from national programmes for VBD control, district health offices, local government and other public sectors, the private sector, civil society organizations and the community. The amount and type of resources depend on the diseases and vectors targeted. For example, vectors that breed predominantly in irrigated agriculture require strong engagement from the agriculture sector, whereas vectors that breed in the peri-domestic environment might require community participation in the removal of breeding sites. Vector control programmes and other units in the Ministry of Health, along with other sectors may contribute to IVM financially. However, other contributions including human resources (e.g. expertise or personnel time) and material resources (e.g. equipment, fuel, transport, commodities) are equally important and should be encouraged.

The methods selected for vector control also have implications for the types of resources needed. For instance, IRS requires trained spraying teams under proper supervision, which often demand substantial financial and logistic support. Local requirements for capacity-strengthening should also be identified. Investment in training and refresher training of staff and volunteers should be promoted. The role of community members, community health workers and agricultural extension workers could be enhanced relatively quickly by practical short courses on vector biology, ecology and control methods. The experience of the agricultural sector in training farmers in integrated pest management could be used (see Box 5.7).

## 6.1 Financial resources

Typically costing is done at the national level based on a strategic plan with clear terms of reference. Sources of financing for IVM will differ by country but typically there are two sources; external donor funding such as that from the Global Fund or Presidents Malaria Initiative or in-country funding, for example from tax revenues or reprioritising country budgets. Funding from donors is likely to remain disease specific to some extent. However, it is possible to include activities or commodities which cut-across diseases in these proposals. For example, Global Fund proposals could include developing capacity in entomological surveillance which would be of benefit to other VBD programmes if these programmes worked in a more integrated manner. Innovative financing mechanisms such as social insurance should also be considered.

Funding for the ISC should be provided centrally by the government since a committee funded by project funds will not be sustainable.

One important aspect of IVM programmes is that cost savings can be made by using one intervention against more than one co-endemic diseases and by sharing entomological expertise, field visits, transport and equipment more efficiently across VBDs. Savings can also be made in the long term by using interventions outside the health sector. For example, well-constructed drainage channels may provide a long-term solution to reducing anopheline and culicine breeding sites in urban areas. In this situation the cost of control could be met by the Department of Public Works and not the Health Department. Encouraging other sectors to contribute resources, particularly financial resources, will require strong advocacy from the ISC and the Ministry of Health.

## 6.2 Human resources and capacity building

The IVM strategy requires skilled staff at central and local levels. Training, support and career structures are required to be able to effectively plan, monitor, evaluate and manage IVM programmes. Clear job descriptions and careers structures need to be put in place. For example, in South Africa, Sudan and Zimbabwe there are clearly defined cadres of public health entomologists with different job descriptions, from national senior entomologist, entomologists at state level, assistant entomologists and mosquito collectors [268]. Clear career structures which outline competencies and opportunities for advancement are an important incentive for people to seek training and help to retain staff [269].

Human resources should be shared both within and external to the health sector in pursuit of IVM. Sharing human resources starts with the effective communication of IVM objectives, indicators and expected targets and outcomes within the health sector and beyond. Transparency is the key to

identify the most cost effective way to deliver health services in affected communities to benefit all involved. Figure 6.1 provides an example of human resource sharing within the health sector to support an IVM approach using IRS and LSM to control lymphatic filariasis and malaria vectors in affected communities. Human resources could be shared in a similar fashion between the health sector and other sectors.

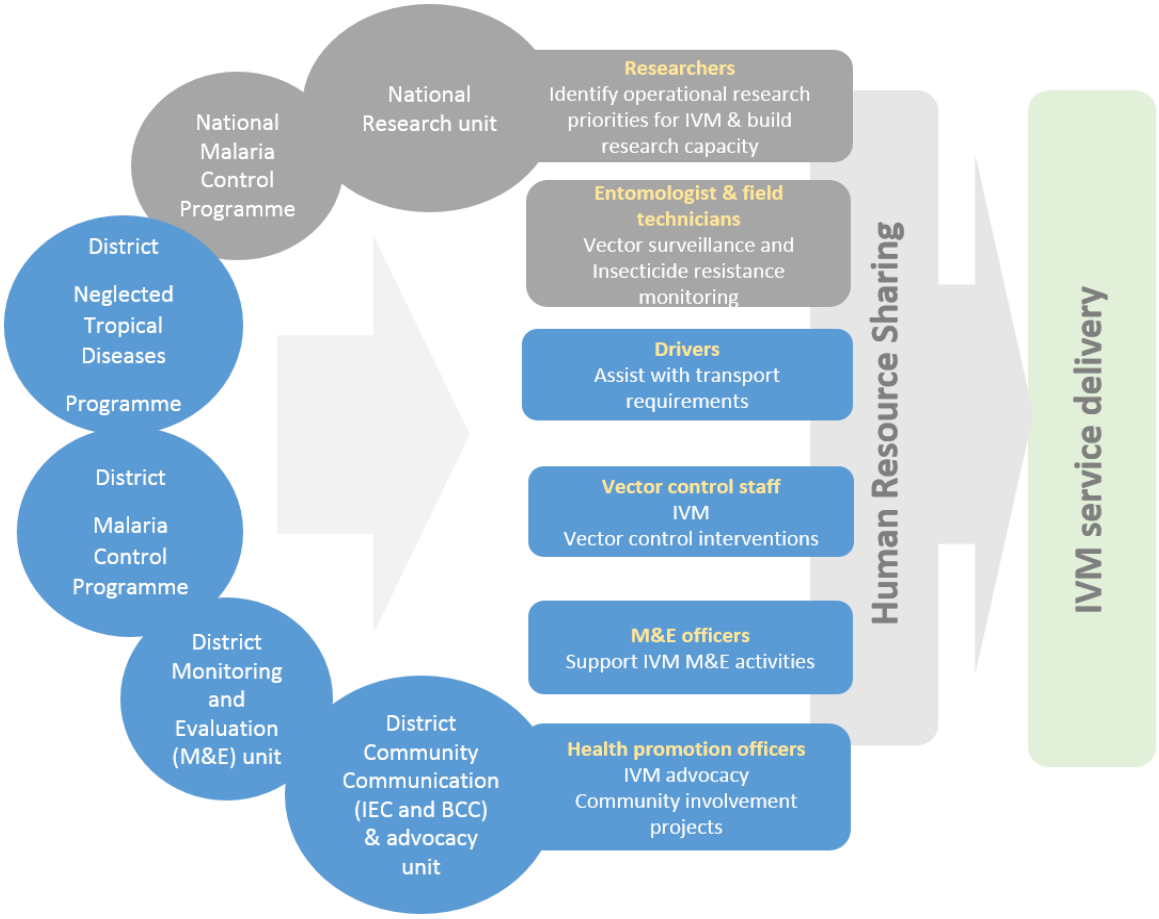



**Figure 6.1: Example of human resource sharing to support an IVM approach at district level.**

Capacity building and supportive supervision should be strengthened. Useful training resources include the Core Structure for Training Curricula on IVM [267] which provides advice to regions and countries on preparing their own training curriculum for IVM. The training curriculum document does not duplicate existing specialised courses on medical entomology and vector control since these materials are likely to be familiar to VBD programmes.

Training provided should be based on a training needs assessment carried out by the Ministry of Health in relation to their Training Curricula on IVM to ensure that training is directly relevant to the expected skills of the cadre. However, key capacity gaps may include project management skills, geographic information systems (GIS), mobile communication technology and information communication technology to enable more effective collection and response to entomological and epidemiological field data [268, 270]. These tools are increasingly being used to refine strategies, target interventions in space and time (see Box 5.1 for how surveillance data has been used to target interventions in South Africa) and monitor and evaluate their impact. Capacity building in entomological surveillance is essential given the importance of this to deploy interventions correctly

based on vector ecology and behaviour, and evaluate the impact or interventions, including on insecticide resistance.

Efforts should be made to strengthen collaboration between VBD control programmes and national universities / training institutions, perhaps through the establishment of formal agreements [270]. Research capacity strengthening and training on other activities could also be provided by national universities, training and research institutions or overseas research institutions. A directory of African institutions with existing capacity for training in IVM has been produced [271]. Establishing a network of training and mentoring opportunities for staff including public health entomologists and monitoring and evaluation staff is essential. Box 6.1 outlines examples of a number of medical entomology courses which are available [268]. Cross-border collaborations such as the Lubombo Spatial Development Initiative (Box 5.11) can also be beneficial for capacity building since training resources are shared across countries.

Retention of staff and the institutional memory on IVM should also be considered. It is important that IVM activities are not solely dependent on key individuals and that training documents and SOPs are developed.

**Box 6.1: Examples of entomological capacity building opportunities [268]**

**Master of Science (MSc) course in Medical Entomology and Vector Control**

The MSc was launched in 2008 by the Blue Nile National Institute for Communicable Diseases (BNNICD) at University of Gezira, Republic of Sudan, in collaboration with London School of Hygeine and Tropical Medicine, Liverpool School of Tropical Medicine and Witwatersrand University. The course is supported by WHO Eastern Mediterranean Regional Office (EMRO) and was initiated through an EMRO Regional Committee resolution in which IVM was endorsed as the regional strategic approach for VBD control and capacity was identified as a key requirement. Over 80 people from 12 countries of the African and Eastern Mediterranean WHO regions have been trained over the past 3 years.

**International Masters Degree in Entomology**

This course is run jointly by the Institute for Research and Development (Benin), Montpellier University (France), Abomey-Calavi University (Benin) and the Entomological Research Centre of Cotonou (Benin). Topics covered include systematics, biology and ecology of vectors of medical interest and epidemiology and control of VBDs. In the first 6 years of the course since inception in 2006, a total of 91 students from 24 countries have graduated from the course.

## 6.3 Infrastructure (research/training/technical and operational facilities)

Adequate infrastructure should exist in order to plan and implement an IVM programme. Activities should be built around established structures which exist within VBD control programmes. There may be opportunity to share facilities and equipment with the National Malaria Control Programme which in sub-Saharan Africa likely to be the most well-resourced vector control programme. In particular, infrastructure such as entomological laboratories for vector collection, rearing, identification and bioassays may need to be upgraded and an insectary should exist at least at

national level that is able to maintain a susceptible *Anopheles* colony for insecticide resistance assays [268].

Strengthening information systems for IVM should be a priority. Information, communication technology and mobile technology communication infrastructure should also be upgraded to provide fast and accurate information collection and assessment, for example tablets for remote collection of data.

## 6.4 Tools and resources for resource planning

To help estimate the financial resources needed for an IVM programme one could use the Tool for Integrated Planning and Costing (TIPAC) (http://www.ntdenvision.org/resource/tipac_multilingual). TIPAC is an Excel program that can be used for estimating the costs and funding gaps of public health programmes, including IVM programmes. It can be used in conjunction with existing national strategic plans and budgets in order to effectively plan and coordinate future programme resources. The program is not a substitute for a plan of action or programme budget but it can help with resource planning and revising a national plan to meet resource constraints.

The OneHealth Tool (OHT) can be used to determine the financial requirements associated with scaling up malaria interventions, as well as health impact projections, health systems planning, scenario analysis and fiscal space analysis [272]. It has been used by a number of countries for national strategic planning and costing purposes. Other VBDs are not included in this tool as yet.

Although to meet the target of universal LLIN access, WHO recommends that one LLIN be distributed for every two persons at risk of malaria, many households have odd numbers of people. Therefore when procuring LLINs, WHO continues to recommend using an overall ratio of one LLIN per 1.8 persons in the target population [35, 273]. WHO's IRS operational manual provides guidance on costing, budgeting and financing [36]. An example of items that need to be costed in an IRS programme is shown in Table 6.1.

**Table 6.1. Example of capital and operational budgets for an IRS campaign (adapted from [36])**

| ITEM | NO OF UNITS | UNIT COST | TOTAL COST |
|---|---|---|---|
| **CAPITAL** | | | |
| Baseline epidemiological and entomological review and survey | | | |
| Environmental impact assessment | | | |
| Compression sprayers | | | |
| Equipment, spares and replacement parts | | | |
| Tool kits | | | |
| Protective sheeting to cover household goods | | | |
| Transport: truck/boats for 3–4 spray teams | | | |
| Transport: supervisors' motorcycles | | | |
| Transport: coordinators' 4 X4s | | | |
| Malaria camps – storage and base | | | |
| **RECURRENT** | | | |
| Spray insecticides including buffer stocks | | | |
| QA / QC of IRS | | | |

| | | | |
|---|---|---|---|
| Salaries of spray operators for 4–8 weeks (adjust to minimum wage) | | | |
| Personal protection equipment (overalls, gloves, helmets, face shields with screen) | | | |
| Collection and disposal of empty sachets and containers | | | |
| Travel and per diems for supervisors and coordinators for duration of the campaign | | | |
| Transport hire and fuel costs | | | |
| Annual training of coordinators and supervisors | | | |
| Annual training of spray operators | | | |
| Annual IEC and campaigns (community mobilization materials) | | | |
| Annual review of environmental compliance and pesticides management | | | |
| Monthly, quarterly and annual operations management meetings | | | |
| IRS data entry and summary reports sheets | | | |
| Malaria prevalence surveys (optional) | | | |
| Entomological studies and sentinel sites | | | |
| Annual post spray review and annual report production | | | |

Decision making and financial planning for tsetse control is complex due to the large number of variables which need to be decided on – for example location, timing, strategy and methods employed. Decision support and costing tools available for human African trypanosomiasis vector control include 'Tsetse Plan' (planning of community-based operations using bait technologies), 'Tsetse Muse' (planning large-scale tsetse control operations using any method and HAT-trick (operations intended specifically to control sleeping sickness). All of these tools can be downloaded from the www.tsetse.org website. A useful paper by Shaw *et al* describes the costs of tsetse control operations in a hypothetical area of 10,000km$^2$ located in south-eastern Uganda [168].

**CHAPTER SUMMARY**

- An inventory should be made of the financial and human resources and infrastructure available and required for vector borne disease (VBD) control at national, provincial or district level.
- It should also be noted that resources can be engaged from other sectors depending on the type of interventions put in place.
- A number of tools are available to assist with resource planning.

# 7 Operational and implementation research to support IVM

Integrated vector management (IVM) programming should be evidence-based – ideally founded on sound operational research and surveillance data. Countries should identify operational and implementation research questions around IVM planning and implementation in their setting. A working group under the IVM Steering Committee (ISC) could be tasked with identifying suitable operational research questions. Some of the types of questions which could be answered using operational research are outlined in Box 7.1. Many of the study questions outlined in Box X are illustrated with practical examples in this toolkit.

**Box 7.1: Types of questions which could be addressed using operational research**

| | |
|---|---|
| Efficacy | • What is the added benefit of larval source management (LSM) on top of long-lasting insecticidal nets (LLINs) for malaria control? |
| Delivery | • Can community health workers delivering preventive chemotherapy be tasked with larviciding of breeding sites?<br>• Use of community groups to conduct environmental management?<br>• Use of community members to install, maintain and monitor traps for tsetse control? (Box 5.8) |
| Targeting | • Is targeted use of indoor residual spraying (IRS) for leishmaniasis more effective than blanket spraying?<br>• Are people living next to irrigation canals more likely to suffer from malaria?<br>• Can geographical information systems (GIS) be used to target interventions more effectively at district level? |
| Community mobilisation / acceptability / adherence | • How effective are behaviour change communication radio spots for increasing adherence to use of LLINs?<br>• Does an educational intervention on dengue transmission and prevention in schools increase knowledge of pupils and their families? |
| Cost / cost effectiveness | • Is community health worker led IRS more cost effective than vector control programme led IRS? (Box 7.3) |
| Surveillance | • Use of mobile technology to collect information on cases from peripheral health centres. (Box 8.2)<br>• Use of school children to identify rodent habitats for zoonotic leishmaniasis?<br>• Use of community members to operate and collect mosquitoes from window traps<br>• Use of community members to identify and conduct larval surveillance of breeding sites (Box 9.2) |

To answer these operational research questions, different study designs will be required. Studies measuring efficacy of an intervention will use an experimental design and are often randomised. Studies looking at the feasibility of community delivery of interventions may assess process indicators looking at training, intervention coverage, cost and resource use and community satisfaction. Studies looking at adherence will usually measure adherence using cross-sectional

surveys of community members using questionnaires. A good general resource for field trials of different types is the book 'Field Trials of Health Interventions in Developing Countries: A Toolbox' [274].

## 7.1 Assessing the efficacy of vector control interventions which do not have WHO approval

Vector control interventions which do not have WHO approval require robust clinical trials to assess their efficacy against epidemiological outcomes. For an intervention to receive a recommendation from the World Health Organisation (WHO) it needs to show a public health impact. In addition, entomological outcomes may also be assessed to help support the clinical findings. Interventions tested are often thought to have a community effect on the vector population (e.g. LLINs, IRS), killing so many vectors that they reduce the survival of the whole vector population, helping to reduce the proportion of older vectors, those most likely to be infective. These studies are generally cluster-randomised controlled trials whereby communities or geographic areas are randomly allocated to control and intervention. Studies need to be conducted in a rigorous manner with adequate sample sizes so that they are powered to answer the question they set out to answer.

In order to conduct these sorts of clinical trials we would recommend that VBD control programmes partner with research institutions in-country or overseas.

**KEY POINT**

Should you wish to test new interventions, perhaps developed in your country or elsewhere, it is a good idea to partner with academic or research institutes who will be able to share their knowledge on how to design, evaluate and analyse complex studies. Your study plan should ideally be checked by someone with expertise on study design and implementation.

## 7.2 Piloting and scaling up recommended vector control interventions

Interventions that have WHO approval, for example World Health Organisation Pesticide Evaluation Scheme (WHOPES) approved insecticides for IRS or larvicides for LSM, have a robust evidence base and do not generally require robust randomised controlled trials to be conducted in country before scaling up. Of course, it is important to make sure that local entomologic and socio-behavioural parameters are measured to ensure that, for example the feeding or resting behaviour of vectors and community acceptance are in support of the intervention. When implementing additional interventions, we recommend starting small (for example in a district) and monitoring and evaluating their effect before going to scale. Small pilots provide a learning opportunity to refine implementation of the vector control method and train staff before scaling up.

In terms of study design for the pilot implementation, it is recommended to have a minimum of a controlled before-and-after design with entomological data collected before and after introduction of the intervention. A diagrammatic representation of a controlled before-and-after study is given in Figure 7.1.

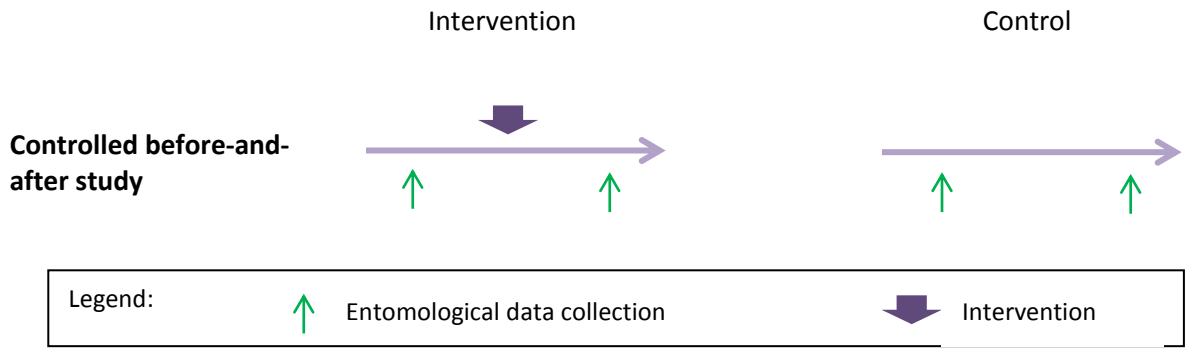



**Figure 7.1: Schematic illustrating features of a controlled before-and-after study**

Pilot studies should include between 1 and 4 clusters i.e. communities or defined geographic areas in each group. Since vector density is often highly dependent on weather, in particular rainfall, it is a good idea to collect environmental data alongside entomological data. Ideally, you should have a control site where the intervention has not been implemented but entomological measurements are conducted in the same fashion as the intervention site. This can help to control for other factors which may be affecting your data. A randomised trial would be better since by randomisation one is more likely to have similar villages (or in urban areas, sites) in either arm of the trial. For example splitting a sentinel site into two areas and randomly assigning each area to receive either the intervention or control is a good idea. If the interventions are allocated randomly there may not be any need to collect baseline entomological data, although if your number of clusters is small it is good practice to do this anyway.

We would also recommend collection of entomological data for at least 4-6 months both pre-intervention (baseline) and post-intervention, if feasible, or for a whole transmission season if possible. However, this depends on the seasonality of transmission and the urgency for control. Ideally, the sampling sites for entomological data collection should be selected randomly. Minimum expected requirements for the pilot study, alongside stricter requirements for a higher quality study are given in Table 7.2.

**Table 7.2: Minimum and improved pilot study requirements**

| Criteria | Minimum requirement | Improved |
|---|---|---|
| Control site | Control site | |
| Randomisation | Non-randomised allocation of areas to intervention and control | Randomised allocation of areas to intervention and control |
| Pre-intervention data | Four to six months of baseline entomology data from intervention and control areas | One year or transmission season of entomology and clinical data from intervention and control areas |
| Post intervention data | Four to six months of post-intervention entomology data from intervention and control areas | One year or transmission season of entomology and clinical data from intervention and control areas |
| Data collection | Entomological and environmental data (e.g. rainfall) | - |

| | | |
|---|---|---|
| Replication of study units | At least one data unit (e.g. village or area) per arm. | More than one data unit (e.g. village or area) per arm or number of data units justified by sample size calculations to show an effect on entomological and/or clinical indicators. |
| Selection of sites for entomological monitoring | Non-random selection of sites for entomological sampling. | Random selection of sites for entomological sampling. |

The effectiveness of the intervention against entomological criteria should be evaluated. Epidemiological data can be collected but often this requires a study with a large sample size (with adequate power) to detect an effect. We would recommend scaling up an intervention that reduces adult vector density by at least 50% [44, 275]. As well as measuring the effectiveness of the intervention, pilot studies should be used to learn and develop best practice. Sentinel sites can then serve as training sites for regional VBD control programmes should the intervention be rolled out.

**KEY POINT**

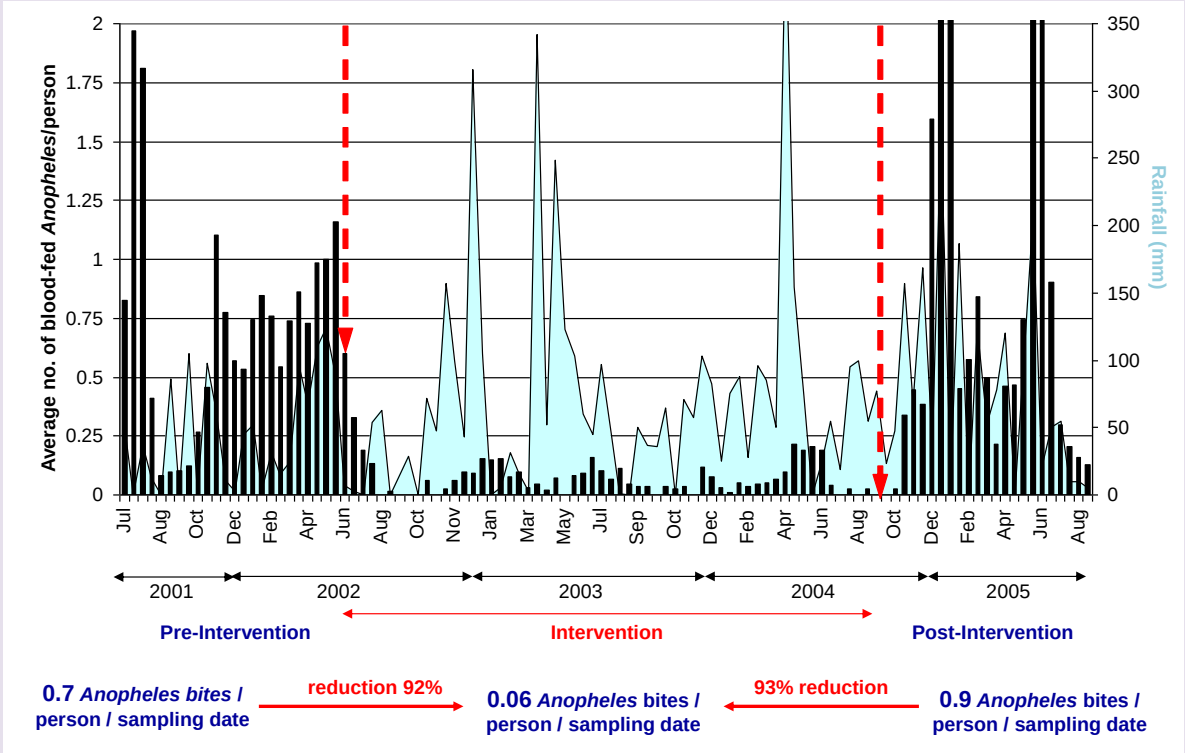
If your resources are meagre, then test the new intervention in two similar locations. Collect baseline entomological baseline for at least four to six months. Then flip a coin so that you randomly assign the new intervention to one of the two sites and try out the new control method. Collect entomological data in both villages for a further four to six months.

An example of a simple pilot study which utilised a before-and-after design to assess the effect of microbial larvicides on malaria vectors in Kenya is provided in Box 7.2.

**Box 7.2: Controlled before-and-after study to assess contribution of microbial larvicides and LLINs for malaria control in Western Kenya** (adapted from [276])

A small pilot study of the use of microbial larvicides was conducted in a 4.5 $km^2$ area in and around a large village in rural western Kenya. The pilot study utlised a non-controlled before-and-after design. From mid-June 2002 to mid-September 2004 (the intervention period) mosquito larvae were controlled using *B. sphaericus* and *B. thuringiensis var. israelensis*. Adult and larval surveys were conducted for 12 months before and after the intervention period (non-intervention periods). No control site was used.

Application of larvicides reduced the proportion of aquatic habitats containing *Anopheles* larvae from 51% during non-intervention periods to 7% during the intervention. The occurrence of late instar *Anopheles* in habitats was reduced from 39% and 33% in pre-intervention and post-intervention periods to 0.6% during intervention. Overall, larviciding reduced *Anopheles* larval density by 95% and human exposure to bites from adults by 92%. The estimated cost of providing this protection to the human population in the study area was less than US$ 0.90/person/year.




**Blood-fed *Anopheles* adults [Williams mean values of *An. gambiae* (97%) and *An. funestus* (3%) combined] per person per sampling date during non-intervention and intervention periods (black bars) in relation to rainfall pattern (blue area, fortnightly sum in mm).**

## 7.3 Other operational and implementation research questions

Alongside efficacy of vector control interventions, there are a number of other aspects that one might be interested in researching: for example cost and cost effectiveness, targeting of interventions and feasibility of community-based delivery or surveillance. Box 7.3 provides an example of a pilot study which assessed the feasibility of community-based IRS, which also looked at resources used, cost, coverage and satisfaction.

**Box 7.3: Implementation of vector control by health extension workers in Ethiopia [277]**

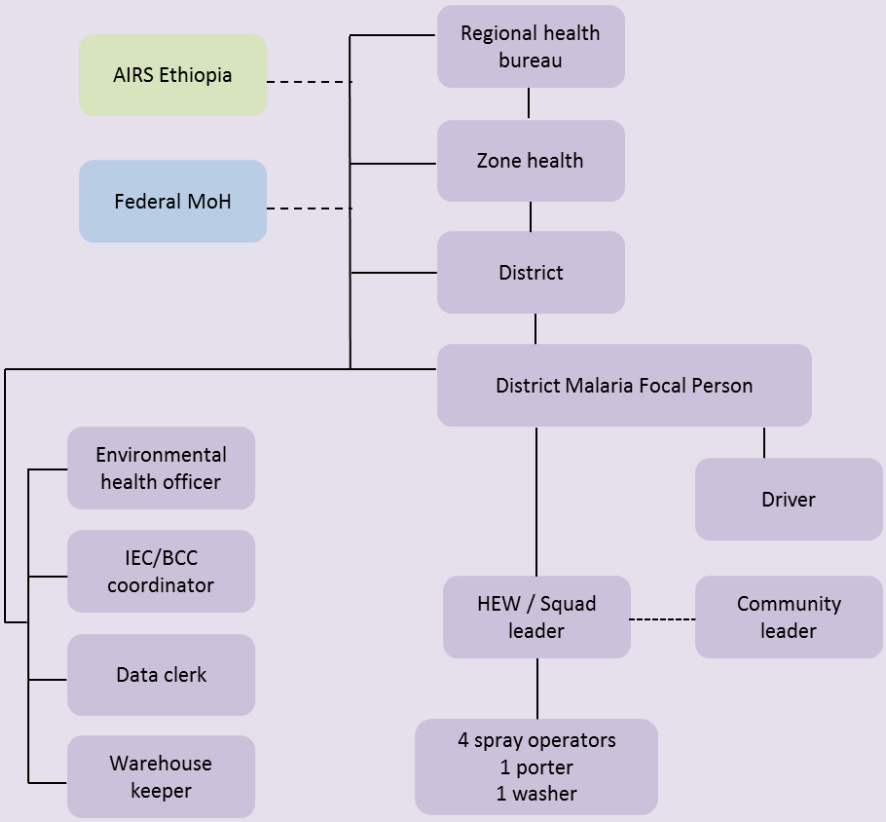
Ethiopia has a health extension programme with the aim of increasing access to basic curative and preventative healthcare in rural areas. The government have trained about 34,000 community-based health extension workers (HEW) and deployed them to village health posts in 15,000 rural kebele (smallest administrative unit consisting of about 1000 households), with two HEW in every kebele of about 5000 people.

IRS is the main component of malaria vector control in Ethiopia. Normally IRS is district led with spray operators hired from towns in the district that travel out to villages from one of two district operation sites in vehicles to conduct the IRS. However, in many cases operators are not familiar with the villages and are not trusted by communities and costs of travel to the villages and camping equipment can be large. In 2012 a President's Malaria Initiative (PMI) funded pilot study by the Africa Indoor Residual Spraying project (AIRS) trained existing cadres of HEW to implement community-based IRS in one district.

In the programme each kebele had its own spray squad – each led by a HEW acting as squad leader who assumes responsibility for managing store rooms, washers, operators, and the data collection and reporting processes. Operation sites were set up in the health posts. The HEW supervises all members of the spray squad (consisting of four spray operators, a washer/guard and a porter, all paid staff) who are recruited from kebele. Around four squad leaders are supervised by one district expert or team leader, who is themselves supervised by the Malaria Focal Person (MFP) for the District. The MFP is in charge of the entire operations. The Environmental Health Officer also closely supervised the operation. A clerk stationed at the District Health Office was responsible for daily data entry and reporting. The figure illustrates the staff organogram.

The roles of the HEW are to:

- select capable spray operators and train them on spraying techniques, communication and safe handling of pesticides, in collaboration with district health services.
- consult with community leaders to plan the start and end dates of IRS in the kebele
- lead and supervise the spraying
- mobilise the community to cooperate and participate in IRS operations, including ensuring that all households are aware of the spraying and what they need to do to make their homes ready for the spray operation.
- educate communities about benefits of IRS and what to do after their houses have been sprayed.
- maintain accurate records of activities and use of insecticides.




A train-the-trainer approach was used. HEW were trained over five days by district health staff on key IRS implementation strategies, spray pump maintenance, communication skills and messages, and data recording and reporting. HEW then selected and trained spray operators from the communities. In 20 IRS targeted kebeles, HEWs recruited 100 SOPs (five from each kebele) and taught them for six days on IRS operations in their kebeles, with minimal support from the district health staff and the project.

During 22 days the pilot IRS project sprayed 22,744 structures which accounts for 98% of all eligible structures found. No vehicles were required to transport the spray operators and no camping facilities since spray operators work in the village where they live or nearby. Only one vehicle was deployed for supervision and timely collection of spray operation reports from the kebele. More spray operators were required than for a normal district-led IRS campaign- five from each kebele compared to normal practice where 20 spray operators cover the whole district. Training costs were higher but the team took less time to complete the IRS (22 days versus an average of 31 days for district-led IRS). Although community-based IRS was only marginally cheaper than district-led IRS in this pilot, this was because of initial outlay on construction of soak pits and equipment for each kebele. In the long run, community-based IRS is expected to produce savings of up to 40% compared to district-led IRS. Spray quality was high and feedback on spray operator performance was good. It is thought that a sense of ownership by the HEW and spray operators in serving their own communities contributed to this.

**CHAPTER SUMMARY**

- IVM should be evidence based. This evidence can come from surveillance or operational/implementation research.
- A working group under the ISC should be tasked with identifying operational research questions.
- Operational research can look at efficacy of interventions, targeting, delivery, new methods of epidemiological or entomological surveillance, cost and cost effectiveness and community mobilisation/acceptability or adherence.
- Interventions that are not recommended by WHO generally require testing using robust, well conducted randomised-controlled trials. Research institutions should be brought on board as partners if these types of studies are to be conducted.
- Interventions which have WHO approval but have not been implemented in your country should ideally be piloted at small scale before rolling out. These pilot studies should assess the effect of these vector control interventions against entomological parameters.
- Minimum study requirements would be a controlled before-and-after design with environmental and entomological data collected for four to six months pre- and post-intervention and at least one data unit (e.g. village or geographic area) per arm.
- Pilot studies also provide an opportunity for learning how to optimise intervention delivery and for training staff.

# 8 Vector surveillance

## 8.1 Functions of vector surveillance

Routine vector surveillance should be conducted throughout the life of the integrated vector management (IVM) programme. The purpose and objectives of entomological surveillance will differ depending on the stage of the programme. The stages of programme can be classified as i) preliminary survey, ii) trend or regular observations, iii) foci investigation, iv) spot checks and v) vigilance [278] (Figure 8.1).

**Preliminary surveys** are rapid, short term surveys and employ a limited number of techniques to delineate areas with vector borne diseases (VBD) and allow planning of control measures. They are generally conducted where little or no information on vectors is available and are a first step in baseline data collection.

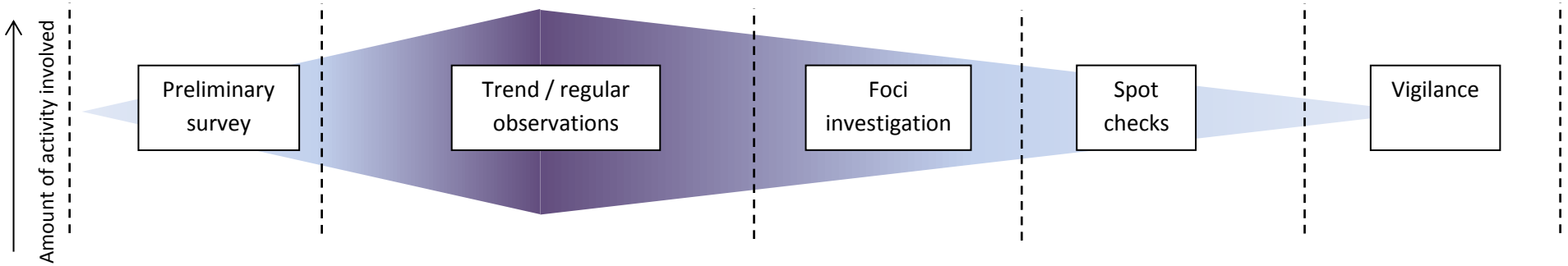
**Trend or regular observations** can be conducted in areas either where no vector control measures are in place or where measures are already in place. Where no vector control measures are in place regular observations can follow on from the preliminary survey and establish in more detail baseline information on the role of vectors in transmission, geographical & seasonal distribution, feeding & resting behaviour and susceptibility to insecticides. Where vector control measures are in place regular entomological surveillance is used to monitor and evaluate the effect of the programme on the vector(s) and is mainly concerned with changes in vector density.

**Foci investigation** is a short term, reactive activity conducted as part of a larger epidemiological investigation. The aim of foci investigation is either to explain the reasons for non-response of vectors to vector control measures, for example due to reduced insecticide susceptibility or to investigate persistence /recurrence of VBD transmission. The trigger to begin an epidemiological investigation can be either clinical (e.g. 'hotspot' of infection or clinical disease or persistence / recurrence of high levels of infection or clinical disease) or entomological (e.g. no changes in vector density over time despite introduction of vector control measures).

**Spot checks** are conducted pro-actively to identify operational shortcomings in vector control measures or to detect changes in effectiveness of control measures e.g. due to insecticide resistance. In this case spot checks should be conducted in areas with high transmission potential or areas where weaknesses in control measures are suspected. Spot checks can also be conducted to check the existence and/or densities of previous vectors in receptive and vulnerable areas as a prelude to more comprehensive vigilance measures.

**Vigilance** refers to entomological surveillance for the purposes of preparedness i.e. identifying and responding to introduction or re-introduction of vectors / disease risks. Surveillance should be conducted in selected localities in areas receptive and vulnerable to new vectors or reintroduction of vectors and should be carried out during the period of high vector prevalence and at the period of influx of sources of infections. Preparedness is mainly concerned with identifying geographic distributions and relative density of vector species, in particular identifying newly introduced vector species, or newly introduced pathogens.

**Figure 8.1: Stages of entomological surveillance activities (adapted from [278]):**




| | | | | | | |
|---|---|---|---|---|---|---|
| Definition | Short term survey employing a limited number of techniques in areas where little or no recent information on vector(s) is available. | Long term observations in fixed locations to follow trends of vector density, species distribution and behaviour over time. | | Short term investigation in established foci of transmission. | Rapid survey employing a single technique for detecting vector resurgence or transmission potential. | Extensive short term spot checks and seasonal trend observations as part of epidemiological vigilance against introduction or re-introduction. |
| Objectives | 1. Delineate areas with VBDs<br>2. Allow planning of control measures<br>3. Initiate collection of baseline data before an intervention is implemented | Areas with **no** vector control measures:<br>1. Establish baseline information on role of vector on transmission, geographical & seasonal distribution, feeding & resting behaviour and susceptibility to insecticides | Areas **with** vector control measures:<br>1. To monitor and evaluate the effect of control measures on entomology | **Reactive** measures as part of epidemiological investigation aimed at explaining the reasons for:<br>1. Non-response to vector control measure.<br>2. Persistence of VBD transmission or recurrence. | 1. To **proactively** identify areas with operational short-comings or to detect changes in effectiveness of control measures e.g. due to insecticide resistance.<br>2. To check existence and/or densities of previous vectors in receptive and vulnerable areas as prelude to vigilance measures. | 1. Check geographical distribution of vectors.<br>2. Determine whether potential vectors have restored levels of high vectorial efficiency in receptive areas.<br>3. Determine reaction of vectors to vector control measures and recommend measures to be taken when faced with re-introduction. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Parameters measured | Vector density<br>Vector geographic distribution | Vector density (seasonal)<br>Vector feeding and resting behaviour<br>Identifying vector habitats<br>Infection* of vectors<br>Susceptibility to insecticides | Changes in vector density<br>Changes in vector infection* rate | Vector density<br>Vector infection* rate<br>Susceptibility to insecticides<br>Vector feeding and resting behaviour | Susceptibility to insecticides<br>Vector density<br><br>Vector presence / absence<br>Relative density of vector species<br>Vector geographic distribution<br>Infection* of vectors | Vector presence / absence<br>Relative density of vector species<br>Vector geographic distribution<br>Infection* of vectors |
| Where to be implemented | Areas designated for VBD control.<br>Conducted where little or no recent information on vectors is available. | In fixed sentinel sites (indicator villages) on basis of information from the preliminary survey. Villages should be sited within larger area where parasitological observations are carried out. | In same sentinel sites as the baseline. | For 1, in representative localities in areas showing non-response to vector control measures.<br>For 2, in all locations showing persistence or recurrence of transmission. | For 1, prioritise areas with high transmission potential or areas where weaknesses in control measures are suspected.<br>For 2, in selected locations in receptive and vulnerable areas. | Selected locations in receptive and vulnerable areas.<br>In a number of locations selected from above for seasonal observations. |
| When to be implemented | Commence in expected season of high vector prevalence. | As soon as information from preliminary survey is available. | After application of the vector control measures. | As soon as epidemiological investigation indicates presence of active foci of transmission (for 1) or persistence / recurrence of disease transmission (for 2). | For 1, during season of high prevalence of vectors taking into account the time lapse after the application of control measures.<br>For 2, during period of high vector prevalence, as well as during period of influx of sources of infections into receptive and vulnerable areas. | Surveillance carried out during the period of high vector prevalence and at the period of influx of sources of infections to receptive and vulnerable areas. Seasonal trend observations should be carried out during season of high vector prevalence. |
| * also infectivity for malaria and LF vectors | | | | | | |

An example of how the different stages in entomological surveillance would flow given introduction of a new malaria control programme utilising indoor residual spraying (IRS) and other measures for is as follows:

- Preliminary survey.
- Regular observations conducted in sentinel sites (indicator villages) to establish baseline data before implementation of vector control measures.
- Regular observations once vector control measures are established to monitor and evaluate the effect on entomological parameters.
- Spot checks to proactively identify areas with operational short-comings or to detect changes in effectiveness of control measures e.g. due to insecticide resistance.
- Foci investigation to investigate reasons for persistence or non-response to vector control measures as the need arises in a prolonged attack.

## 8.2 Parameters to measure in vector surveillance

The different parameters which can be measured in vector surveillance are outlined in Table 8.1. As can be seen from Figure 8.1, a number of parameters can be measured but the most common across all stages of entomological surveillance is vector density. Here adults or immature forms can be measured. Vector density is typically measured as the mean number of vectors (adults or immature forms) collected per sample per day. e.g. 30 *Anopheles gambiae* per light trap per night, number of *Phlebotomus orientalis* per room per night, *Aedes aegypti* indices including house index (percentage of houses infested with *Aedes aegypti* larvae and/or pupae). When collecting adult vectors it is typically only females that are counted since only this sex feeds on people and can transmit the disease (except for tsetse where both males and females are capable of transmission). Identifying the species of vector is critical. This can be done using established taxonomical keys, although in some cases morphologically identical species can only be separated using molecular techniques requiring a laboratory. Countries without the capability to assess species using molecular techniques should develop their capacity in this area. In some situations it may also be important to measure infection in the vectors. This can be done morphologically e.g. microscopic examination of mosquito salivary glands for the presence of sporozoites or may involve laboratory tests e.g. reverse-transcriptase polymerase chain reaction (RT-PCR) for arboviruses.

If the event of a new VBD spreading, then it may be important to assess the competence of your local vectors to this new pathogen e.g. West Nile virus, Rift Valley fever, Japanese encephalitis. If possible, this should be done by specialists within the IVM group or expert advice should be sought to do these important studies.

Along with vector density, there are a number of other factors which need to be measured. It is essential to measure the susceptibility of your local vectors to locally-used vector control insecticides at regular intervals. More information on insecticide susceptibility and how this can be measured is given in 8.6.

Density of some vectors is heavily dependent on weather patterns including rainfall and temperature. Weather information should be collected on a routine basis or obtained from meterological partners.

**KEY POINT**

When conducting vector surveillance it is very important to take measurements of latitude and longitude using a global positioning system (GPS). This is so that you can map the vector distribution.

**Table 9.1: Parameters which should be measured in a vector assessment in sub-Saharan Africa**

| Parameter | Questions answered | How measured? |
|---|---|---|
| Vector density | Vector presence / absence<br>During which times of the year are vectors most prevalent?<br>What is the geographic distribution of the vector?<br>What habitats do vectors occupy (adults / immatures)? | Adult or immature vector catches.<br>Longitudinal density surveys.<br>Species identification (species complex / molecular forms) using identification keys or laboratory tests. |
| Vector feeding and resting behaviour | What is the feeding behaviour of the vectors (humans, intermediates / indoor, outdoor)?<br>Are there reservoir hosts? | Laboratory test e.g. ELISA to determine the origin of blood meal.<br>Animal baited traps.<br>Indoor / outdoor man biting rate comparisons. |
| | Where and when do vectors rest? | Adult resting catches. |
| | When is the vector active? | Repeat vector density catches over a 24 hour period. |
| Infection of vectors | Are vectors infected and with which pathogen? | Microscopic examination e.g. sporozoite rate for malaria vectors or laboratory studies e.g. polymerase chain reaction (ELISA) |
| Insecticide susceptibility | Are there physiological or behavioural adaptations in the vector which are impacting on insecticide susceptibility? | Bioassays (e.g. WHO tube bioassay, CDC bottle bioassay, WHO cone bioassay, larval bioassays)<br>Resistance intensity assay<br>Biochemical enzyme assays<br>Molecular (biological) tests<br>Synergist assays<br>Indoor / outdoor human landing catches |

## 8.3 Methods used to sample vectors

Methods used to sample vectors, along with useful references are described in Table 8.2. The method used may differ depending on the vector species, the life stage you are trying to collect (adults versus immatures) and its habitat.

**Table 8.2: Commonly used vector sampling tools by disease**

| Disease | Tools | Useful references |
|---|---|---|
| Malaria | Human landing catch (HLC), Center for Disease Control (CDC) Light Trap, exit trap, Pyrethrum spray catch (PSC), Larval sampling, odour baited trap, tent trap, resting collection (aspirator) (Figure 8.2) | [279, 280] |
| Lymphatic filariasis | Human landing catch (HLC), Center for Disease Control (CDC) Light Trap (*Anopheles*), Latrine emergence trap, Larval sampling, odour baited trap, tent trap, ovi trap (culicines) | [27] |
| Dengue | Larval sampling (Figure 8.3), pupal sampling, Ovi trap, Tyre larvitraps, resting collections, odour baited trap, gravid trap, aspirator (e.g. battery powered aspirator, Prokopack) | [84, 281-283] |
| Yellow Fever | Larval sampling, ovi trap, | [284] |
| Chikungunya | Larval sampling, pupal sampling, ovi trap, resting collections (aspirator or handheld net) | [285] |
| Leishmaniasis | Center for Disease Control (CDC) Light Trap, Quantitative sticky paper trap, Outdoor/indoor resting catch, Animal baited trap (animal depends on species you are trying to catch), Knockdown catch of sandflies resting indoors, Funnel trap over animal burrow | [29, 286, 287] |
| Human African Trypanosomiasis | Gambiense HAT (riverine) – biconical / pyramidal trap<br>Rhodesian HAT (riverine - Uganda) – biconical / pyramidal trap<br>Rhodesian HAT (savannah) – odour baited / episilon / Nzi trap or fly round | [148]<br>http://www.tsetse.org/ |
| Onchocerciasis | Human landing catch, Larval sampling, odour baited trap, crab catching and examination (*S. neavei*) | [288-295] |
| Schistosomiasis | Snail surveys | [296] |
| Trachoma | Fly trap | |

## 8.4 Standard indicators for vector surveillance

### 8.4.1 *Anopheles* vector surveillance [279, 280]

A common sampling tool for estimating the number of mosquitoes entering houses, a proxy measure of transmission intensity, is the CDC light trap. The two main advantages of this method is that when placed next to someone sleeping under a long-lasting insecticidal net these individuals are protected from biting and this represents a non-biased method of sampling since it is not dependent on the ability of the collector to catch vectors. However, these traps are expensive and the batteries need re-charging regularly. A cheaper alternative for estimating relative numbers of vectors would be to use window traps to collect mosquitoes leaving houses. These can be emptied by the householders themselves. Indicators for *Anopheles* surveillance are indicated in Table 8.3.

**Table 8.3: Indicators for *Anopheles* vector surveillance**

| Indicator | Definition | Sampling technique | Formula |
|---|---|---|---|
| **ADULTS** | | | |

| | | | |
|---|---|---|---|
| Indoor resting density (D) | | PSC | = (Number of females ÷ Number of houses) ÷ Number of nights |
| Man biting rate (ma) | Number of bites a person received from a specific vector species per night | HLC (collections performed during the whole night i.e. 12 hours) | = Number of mosquitoes collected ÷ Number of collectors |
| | | HLC (collections performed for a few hours of the night) | = Number of mosquitoes ÷ Number of collectors ÷ Number of collection hours |
| | | PSC | = Blood fed females ÷ total number of occupants in rooms used for collection |
| | | CDC light trap (approximates to ma) | = number of mosquitoes/per night/per trap |
| Human blood index | Proportion of blood-fed mosquitoes that fed on humans | | = Number of mosquitoes feeding on human blood ÷ Total number of blood-fed mosquitoes |
| Sporozoite rate | Proportion of mosquitoes of a given species found to carry sporozoites in the salaivary glands | Dissection or ELISA | = Number of positive mosquitoes ÷ Number of analysed mosquitoes |
| Entomological inoculation rate (EIR) | Number of infective bites received per person per night | | = [Man-biting rate (ma)] x [sporozoite rate s)] |
| Endophagic index (ENGI) | Indicates indoor biting preference | HLC / CDC light trap | = Man-biting rate indoors ÷ (Man-biting rate indoors + Man biting rate outdoors) |
| Exophagic index (EXGI) | Indicates outdoor biting preference | | = Man biting rate outdoors ÷ (Man biting rate indoors + Man biting rate outdoors) |
| Microfilaraemic index | | | = Number of mosquitoes with microfilaraemia ÷ Number of mosquitoes examined |
| Insecticide susceptibility | | | See 8.6 |
| **IMMATURE** | | | |
| Mosquito breeding index (BI) | Measure of larval density | | = Total number of larvae and pupae collected ÷ Total number of dips performed x Number of breeding sites sampled |
| Habitat occupancy | Percentage of positive larval habitats | | Number of habitats with larvae or pupae ÷ Total number of habitats found |

**Figure 8.2: a) Human landing catch b) CDC light trap and c) window exit trap, clockwise from top left** (photo courtesy of S. Lindsay)

### 8.4.2 *Aedes* vector surveillance

The key indices for immature *Aedes* vectors are: house index (HI= percentage of houses infested with larvae and/or pupae), container index (CI=percentage of water-holding containers infested with larvae or pupae) and Breteau index (BI=number of positive containers per 100 houses inspected) [84]. Pupal demographic indices can also be used, whereby the number of *Ae. aegypti* is expressed per person [84].

Adult density can be expressed as per malaria indicators. Human landing catches are however not recommended since collectors are exposed to dengue and no prophylaxis is possible.

**Figure 8.3: Surveillance for *Aedes* larvae in tyres (photo courtesy of S. Lindsay)**

### 8.4.3 Black fly surveillance

Indicators for black fly surveillance include vector density (number of black fly vectors per trap / unit time), infection rate (proportion of vectors infected with microfilariae) and parous rate (proportion of vectors that have oviposited at least once).

### 8.4.4 Tsetse fly surveillance

Indicators include the average number of tsetse caught per trap per day, proportion of blood-fed flies per total number captured (fed rate) and proportion of tsetse flies that are infected with trypanosomes.

### 8.4.5 Snail surveillance

Surveys for snails may measure positivity of water bodies, density of snails per unit area and/or proportion of snails positive for cercariae when dissected.

Skills and resources of entomologists in VBD control programmes could be shared across programmes to expand vector surveillance activities. This is particularly the case if vector sampling tools, methods or areas where samples are being taken are duplicated across programmes.

## 8.5 Selecting and using sentinel sites

For vector assessment it is recommended to set up sentinel sites for vector surveillance, or use existing sentinel sites (if appropriate). During preliminary surveys the vector control programme managers and entomologists should become familiar with the regions where the programme will work including population distribution, eco-epidemiological areas and accessibility. This early reconnaissance will prove useful for later more systematic and extended surveys when there is a need to establish a network of sentinel sites.

There are a number of considerations when deciding where to set up sentinel sites (adapted from [278]):

1. **Disease endemicity**
   Vector control programme managers should ensure that all VBD are covered by sentinel sites. There may be the potential for overlap in sentinel sites and used of shared surveillance tools depending on the diseases in question, for example malaria and lymphatic filariasis transmitted by *Anopheles gambiae* in rural areas.

   Observations will generally be carried out in areas of high endemicity. Therefore to select sites the vector control programme manager should work jointly with the overall control programme manager to combine knowhow on both entomology and clinical data. Regular collection of data on infection / disease prevalence or incidence should be conducted in the sentinel sites. Therefore, it may be a good idea to establish sites in existing Health and Demographic Surveillance Sites (DHSS) or close to health centres with established, well-functioning health monitoring information systems. Clinical data collected in parallel with entomological data is useful for monitoring the impact of interventions.

2. **Ecological zones**
   Sentinel sites should be selected from different ecosystems within the country or region - village, urban, riceland, river and estuary, small scale farming or plantation. For example, livestock areas may be reservoirs of zoonotic disease, such as Rhodesian human African trypanosomiasis. Identification of the different eco-epidemiological zones present in the country should be have been conducted as part of the broad level disease situation analysis outlined in Chapter 3. Sufficient sites should be selected so that all ecosystems are represented. An example of ecological stratification of Nigeria for the purpose of siting sentinel sites is shown in Figure 8.4. Here a slightly different ecological classification is used [Mangrove, forest, forest Mosaic,

tropical African savannah (Guinea / Sudan / Sahel)] but the same principles apply and sentinel sites are located in each zone.

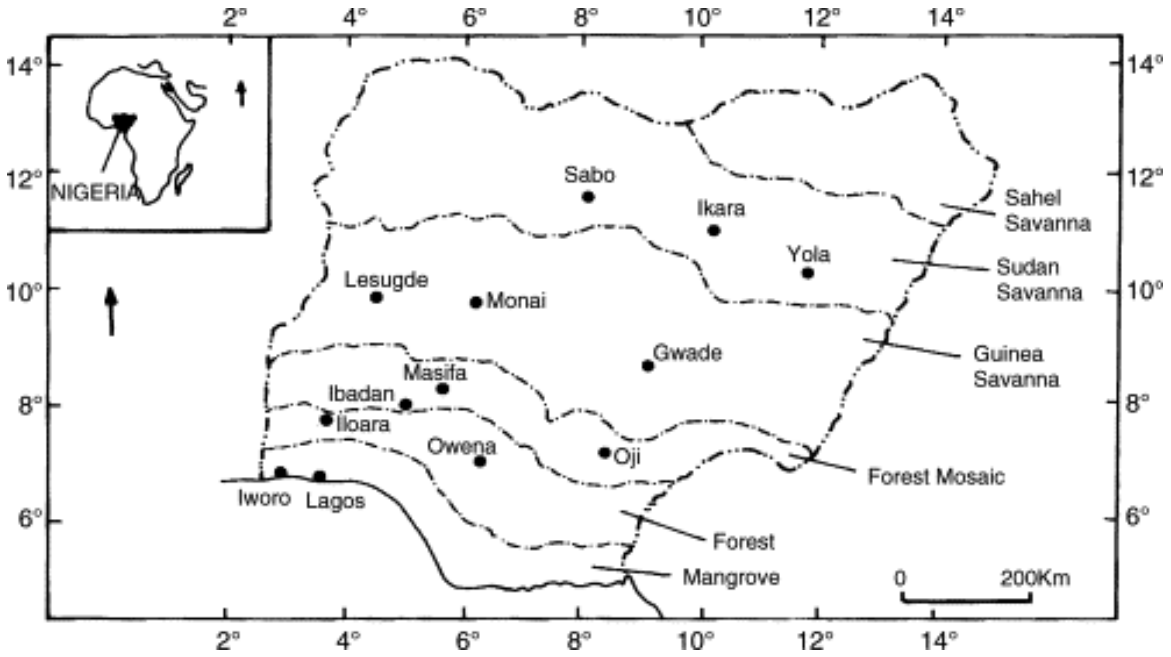



**Figure 8.4: Ecological stratification of Nigeria for purpose of locating sentinel sites (adapted from [297])**

Ecological zones should correspond to some extent to areas of vector dominance, if VBD in the country or region are transmitted by more than one main vector. In certain types of terrain there may be a sharp transition from one dominant vector to another. For example, this is the case with malaria vectors in the Senegambia region. *An. melas* predominates in salt water mangroves of The Gambia, *An. gambiae* s.s. in Upper river regions and *An. arabiensis* in inland savannah areas of Senegal [298].

**3. Areas of different seasonal incidence of the vector**

Seasonal changes in breeding foci will affect the distribution and abundance of vectors within an area. For example, in malaria endemic areas, breeding sites may be widespread and abundant in the rainy season and restricted to perennial streams or swamps in the dry season. Selecting sentinel sites during the rainy season may indicate that *An. gambiae* is the dominant vector and show a drop in density during the dry season, whereas there may be some dry season foci which may have been missed where *An. funestus* is the dominant vector. This needs to be taken into account when selecting sentinel sites and collecting stations within sentinel sites so that we obtain a full picture of vector seasonal incidence related to type and variability of breeding potentialities.

**4. Accessibility of sentinel sites**

Sentinel sites need to be accessible throughout the year so that regular observations can be made. Difficulty in accessing a site to conduct observations due to for example flooding should be anticipated but missing observations for several months at a time due to inaccessibility at a peak time of vector breeding should be avoided.

**5. Areas with high use of insecticides**

Sentinel sites for insecticide resistance monitoring should be placed in areas with high incidence of disease and / or high use of insecticides for either public health or agriculture. Here the threat and potential impact of insecticide resistance is likely to be greatest. The majority of guidance on insecticide resistance monitoring is available for malaria vectors, in particular the Global Plan for Insecticide Resistance Monitoring in malaria vectors (GPIRM) [42]. The WHO Regional Office for Africa [299] and the Presidents Malaria Initiative (PMI) [300] have proposed, as an approximate guide, that there should be at least one sentinel site for insecticide resistance monitoring in malaria vectors per every 500,000 nets distributed or 200,000 houses sprayed. This is equivalent to about one site per 1 million people protected, although the exact number would depend on the country. Small countries should generally have one sentinel site per region.

**6. Number of sentinel sites**

Vector control programme managers are faced with many challenges including scarce financial and human resources, transport and time. Therefore, they may need to make a compromise between selecting a greater number of sentinel sites which are visited less frequently and fewer sites visited on a more regular basis and assessed more fully.

Point 5 discusses how many sentinel sites are required for insecticide resistance monitoring in malaria vectors. Similar recommendations for other diseases vectors are not currently available and although it is difficult to make strong recommendations since each country situation is different, in general we would recommend a minimum of two sentinel sites for a representative epidemiological area although four sites would be preferable. Ideally collections should be made at least monthly during the main transmission season. If a site is not well characterised and seasonality of the vector of interest is not known, then monthly surveys for the entire year are required.

**7. Number and arrangement of collecting stations in sentinel sites**

Appropriate selection of collecting stations, for example houses or animal shelters is critical. The location of collecting stations can be selected purposively or randomly. Purposive selection, for example to encompass different housing types, distances from breeding sites or attractive sites where high vector density would be expected (productive collecting sites) can be useful. This type of selection also allows you to take into account daily or seasonal shifts or movement of vector populations within the sentinel site. However, if you would like to get a representative picture of the level of transmission in your sentinel site that is directly comparable over time and between sites, it is best to select collecting stations randomly. For example, if houses are to be sampled, random selection can be done by mapping your study site, numbering the houses and then randomly selecting several numbers using a random number generator in Microsoft Excel.

Vector control programme managers also need to decide how many collecting stations they will locate per sentinel site – generally this should be between two and three collecting stations per sentinel site.

## 8. Frequency of sampling

The frequency of sentinel surveillance sampling depends on the capacity and needs of the control programmes – for example, the vector in question, what data you are collecting and why. Sampling should be done at a minimum of once a year. Generally, insecticide resistance should be measured every 6-12 months and species composition/density every month. However, this may not always be possible.

An example of the structure and scope of an entomological surveillance system in The Republic of Sudan is given in Box 8.1.

**Box 8.1: Entomological surveillance system in Republic of Sudan [278, 301]**

Sentinel sites were selected to meet the following criteria (Adapted from WHO (1975). Manual on Practical Entomology in Malaria - Part I - Vector Bionomics and Organisation of Anti-Malaria Activities.):

1. Sufficient vector density to allow study of the vector habits, resting, feeding and vector distribution (indoor and outdoor).
2. Representing different geographical and ecological zones
3. History of vector borne diseases transmission in the area.
4. Accessibility of site in the different seasons.
5. Type of dwellings and breeding sites present.
6. Considering livestock areas as a potential burden of zoonotic disease.
7. Considering urban and rural areas.

Sites were selected at first administrative level (State), since this geographic area was considered to fulfil the criteria listed above. Countrywide there are 106 vector surveillance sites with on average 4 to 6 sites per state, except for large states such as Khartoum, the capital of the country (9 sites) and Gezira State, that hosts the largest irrigated agricultural scheme in Africa (7 sites).

Of the 106 vector surveillance sites, 64 monitor also insecticide resistance. Of these 64 sites, 40 sites monitor insecticide resistance annually (irrigated schemes and areas with high use of insecticides for example big cities and Internally Displaced Persons (IDP)/refugee camps) and the remainder monitor resistance only every two years since in these sites insecticides are used seasonally.

Responsibility for conducting surveys is devolved to State / District entomology teams consisting of a Senior Entomologist and three Entomology Technicians who report back to personnel at the Integrated Vector Management (IVM) unit in the Federal Ministry of Health. For the entomological surveillance, target vectors are three genera of mosquitoes, as well as sand flies, ticks and snails where sampling sites neighbour water bodies. Sentinel sites are visited monthly and recommended collection methods are used to sample the insects and snails. State level surveys collect information on vector species, vector density (adult and larvae, including *Aedes* mosquito indices), parity rate, biting rate and physiological status.

Data collected at State level is sent to the National IVM Unit electronically using a standard form. A sub-set of the insects/snails collected are sent to national level for additional analysis, including vector identification and infection rate analysis, for example RT-PCR for arbovirus identification. Once analysed, findings are fed back to the State level in a timely manner. The IVM unit in the Federal Ministry of Health conducts regular supervision to all states a minimum of twice a year to make sure they conduct vector surveillance as planned. In addition, in service training is conducted for State level staff on an annual basis and there are minimum of three meetings a year to discuss the progress of VBD control including vector surveillance.

## 8.6 Responsibility for vector surveillance

Entomological surveillance is usually carried out by vector control personnel. However, in some programmes community members have supported this effort and this is a valid approach given the right training and support is provided. For example, community members participated in entomological surveillance for monitoring and evaluation of IRS using DDT for malaria control in Mozambique [302]. Window exit traps were installed on 6 houses with the home-owners permission at each of 19 sentinel sites in Zambézia province. Home-owners were trained to empty the traps on a daily basis into pre-labelled specimen jars containing isopropanol and complete checklists indicating the nights for which the traps were checked. Specimen jars were then collected by programme staff who assessed species abundance and sporozoite rates. Community members have also been involved in tsetse trapping, monitoring traps and collecting flies in South Sudan (Box 5.8). Another example of using community members in entomological activities is the use of community-based resource persons to map and monitor breeding sites for larval source management (LSM) in Dar es Salaam, Tanzania. How this participatory mapping activity was set up is outlined in Box 8.2 and more information can be found in references [303, 304].

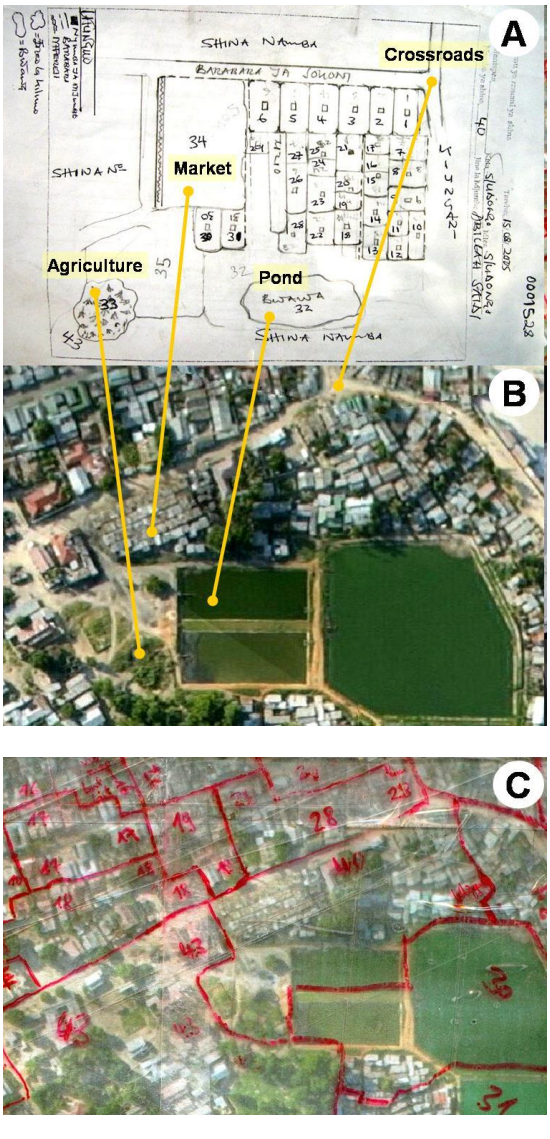
**Figure 8.5: Larval surveillance using dipper** (photo courtesy of S. Lindsay)

**Box 8.2: Mapping of malaria vector breeding sites to facilitate operational larval source management (LSM) in Dar es Salaam, Tanzania (adapted from [304])**

The Dar es Salaam Urban Malaria Control Programme (UMCP) aims to control aquatic-stage mosquitoes using community-based resource persons (CORPs), and to evaluate the effectiveness of this intervention. The UMCP in its current form was launched in March 2004 and operates on all five administrative levels of the city: the city council, three municipalities, 15 wards, 67 neighbourhoods and more than 3000 ten-cell-units. The four upper levels in this hierarchy are responsible for project management and supervision, while the actual monitoring, mosquito larval surveillance and control is organised and implemented at the level of the smallest administrative units, the so-called ten-cell-units (TCUs). A TCU typically comprises about ten houses, in some cases even more than one hundred. On a weekly basis, larval surveillance CORPs monitor and document the larval habitats of mosquitoes in every TCU, receiving minimal remuneration. Since 2006, additional CORPs have been recruited and trained who are responsible for applying biological larvicide (*Bacillus thuringiensis* var. *israelensis*) to all potential larval habitats of malaria vectors.

The mapping procedure involves several steps:

1) CORPs produce sketch maps of the TCUs marking plots (and detailing separately their characteristics and ownership), as well as roads, pathways, drains or other landmarks.
2) Verification of sketch maps through technical teams using laminated aerial photographs in the field which were later digitized and analysed using Geographical Information Systems.




**Example of a sketch map, aerial picture and technical map**. A. Sketch map of a TCU drawn by the responsible CORP. Features comprise plots with continuous numbering, streets, drains, agricultural areas and ponds. B. The same area on the aerial picture. The yellow lines are connecting identical features on the sketch maps and the aerial picture. C. The same area on the laminated aerial photograph used for the technical mapping in the field. Features to be mapped were marked with non-permanent marker pens.

## 8.7 Insecticide resistance

### 8.7.1 What is insecticide resistance?

Insecticide resistance can be defined as "a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species" [305]. Selection pressure for development of resistance results from use of insecticides for public health and agriculture, and may also be driven by household use of insecticides and hydrocarbon pollution [42].

There are 2 key mechanisms by which resistance can occur: behavioural resistance and physiological resistance. In behavioural resistance a vector adapts its feeding or resting behaviour to actively avoid contact with the insecticide. For example, there is some suggestion that malaria vectors may have adapted to bite outside the home and earlier in the evening when individuals are not protected by LLINs [306]. Physiological resistance can be conferred by 3 different mechanisms: metabolic resistance, target site resistance and cuticular resistance. Metabolic resistance involves a change or amplification in the enzymes that metabolize the insecticide meaning that a lower amount of insecticide eventually reaches the target site. Target site resistance involves a genetic mutation which directly impacts on the target site of the insecticide thereby reducing or eliminating the effect of the insecticide. Cuticular resistance occurs as a result of modifications in the insect cuticle which prevent or slow the adsorption or penetration of insecticides.

Cross resistance occurs when resistance to one insecticide confers resistance to another insecticide, even where the insect has not been exposed to the latter product. Cross resistance often occurs where insecticides share a common mode of action, for example *kdr* mutations in malaria vectors can confer cross resistance to both DDT and pyrethroids [42].

### 8.7.2 Testing for insecticide resistance in malaria vectors

The level and intensity of insecticide resistance should be monitored. Two main methods exist for malaria vectors: the WHO tube test and CDC bottle assay [307, 308]. Either or both types of tests may be used but the results are not directly comparable. The WHO tube test exposes mosquitoes to discriminating concentrations of insecticides on impregnated papers [308]. Test kits and insecticide-impregnated papers are prepared on behalf of WHO by a third party. Procedures and conditions for procuring test kits and impregnated papers are available [309]. The test used and procedures, including any deviation from the standard protocol should be documented.

A mortality of less than 98% (as long as mortality in the control tubes remains below 5%) 24 hours after the one hour exposure period is suggestive of the existence of resistance and further investigation is needed [308].

**KEY POINT**

A mortality of less than 98% in tests that have been conducted under optimum conditions of temperature and humidity with a sample size of at least 100 mosquitoes, replicated two or three times using fresh impregnated papers (i.e. before the expiry date on the box) that have not been used more than six times and whose efficacy is confirmed with susceptible mosquitoes, is a strong suspicion of resistance and requires further investigation of the mechanism of resistance.

To measure insecticide resistance intensity, mosquitoes are exposed to discriminating concentrations of insecticide for differing time periods so percentage mortality can be plotted over time (50% lethality time, $LT_{50}$; see [310] for example). Guidelines are being prepared on how to measure intensity and this measure may be useful for measuring changes in resistance over time.

Where insecticide resistance is confirmed, then it is recommended to conduct additional testing to identify the mechanism of resistance (e.g. kdr, metabolic resistance, behavioural resistance etc.). Countries should draw on WHO and research institutes for assistance, as required.

If insecticide resistance is identified at a site, then the programme should drill down and conduct more intensive sampling at that site and in the neighbouring area. Insecticide resistance is often very focal and presence or absence, intensity and mechanisms may vary over short distances. Insecticide resistance data should be coupled with other data sources, in particular epidemiological data from Health Management Information Systems (HMIS) and data on intervention use/coverage to gain a full picture of the situation. Data on use of insecticides in other sectors, such as the agricultural sector should also be examined.

More information on the WHO strategy against insecticide resistance is provided in the 2012 WHO Global Plan for Insecticide Resistance Management in Malaria Vectors (GPIRM) [42]. A Framework document which helps countries to develop their own national insecticide resistance monitoring and management plans is being prepared by WHO.

**KEY POINT**

Insecticide resistance data should be viewed in tandem with other data sources including epidemiological data, data on intervention use and coverage and use of insecticides in other sectors e.g. agricultural sector to gain a better picture of the impact of insecticide resistance on operations.

### 8.7.3 Testing for insecticide resistance in non-malaria vectors

The procedures for measuring insecticide susceptibility are well documented for malaria vectors, and generally involve WHO tube assays or CDC bottle assays [307, 308]. The same techniques can be applied for other mosquito vectors, including lymphatic filariasis and dengue vectors, although care

should be taken to make sure you are using the correct discriminating dose. Key documents and specific guidance for non-malaria vectors is given in Table 8.4.

**Table 8.4: Measuring insecticide susceptibility of non-malaria vectors - useful resources**

| Disease | Vector | Resources |
|---|---|---|
| Lymphatic filariasis | *Culex* spp.<br>*Aedes* spp.<br>*Mansonia* spp. | [27] - Annex 5 gives methods for monitoring and managing resistance to insecticides |
| Leishmaniasis | *Phlebotomus* spp. (Old World)) | [311], [27] - gives advice on testing susceptibility to insecticides and strategies for preventing development of resistance |
| Onchocerciasis | *Simulium* spp. (Black fly) | [311, 312] |
| Dengue | *Aedes aegypti* and *Aedes albopictus* | [84] - gives advice on testing susceptibility to insecticides |

## 8.7.4 Current status of insecticide susceptibility

### 8.7.4.1 Malaria Vectors

Vector control, particularly LLINs and IRS is a critical component of malaria control strategies. Only 4 classes of insecticide are used as adulticides: pyrethroids, organochlorines (dichlorodiphenyltrichloroethane, DDT), organophosphates and carbamates. Currently, pyrethroids are the only class of insecticide available for use on LLINs. It is therefore of great concern that there has been a rapid increase in the distribution and intensity of resistance in malaria vectors in sub-Saharan Africa, with resistance being reported in nearly two thirds of countries with ongoing malaria transmission [42]. Insecticide resistance has been reported in all major malaria vectors and involves all classes of insecticide (but particularly pyrethroids). At the moment there is no strong evidence that this resistance is actually compromising malaria control. For example, a recent review did not find evidence that insecticide resistance was attenuating the effect of ITNs on entomological outcomes [313]. However, the distribution and intensity of resistance is increasing very rapidly in many parts of Africa and therefore, it is considered that it is only a matter of time until the effectiveness of malaria control is reduced or at the extreme control failure becomes apparent.

Information on the status of insecticide resistance in malaria vectors can be found in the GPIRM document [42] and on the website Insecticide Resistance Mapper (www.irmapper.com) [314, 315]. An example of the maps produced by this website is shown in Figure 8.6. This website consolidates published reports of insecticide resistance in malaria vectors onto filterable maps to inform vector control strategies. Where lymphatic filarasis is transmitted by *An. gambiae* information on insecticide susceptibility can also be obtained from this website. Another source of insecticide resistance information is IRBase (https://www.vectorbase.org/irbase) which includes published as well as unpublished data. However, this database has fewer datapoints and is not updated regularly. Insecticide resistance datapoints from border regions of neighbouring countries should also be assessed.

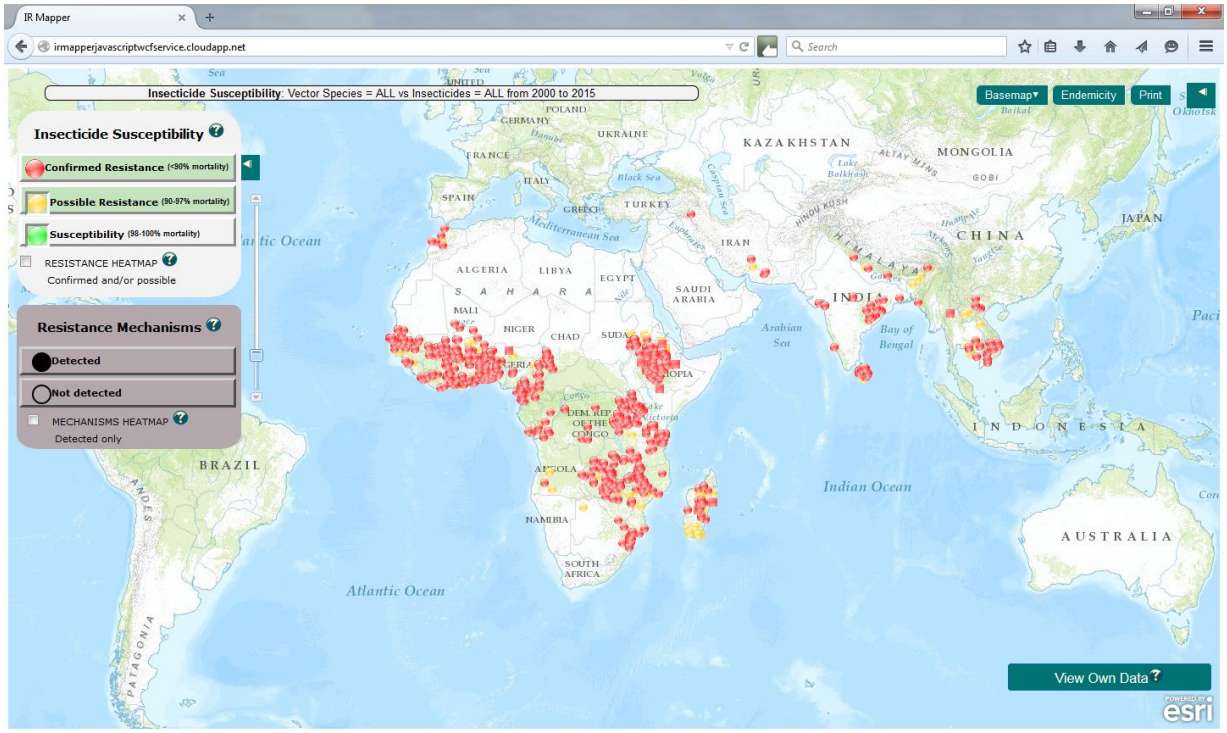



**Figure 8.6: Screenshot from Insecticide Resistance Mapper (www.irmapper.com) showing locations of confirmed (red dots) and possible resistance (orange dots) of all malaria vectors to all classes of insecticide from 2000 to 2015 (accessed 30th March 2015) [314]**

### 8.7.4.2 Other disease vectors

Insecticide susceptibility is less well characterised and documented in other vector species [222]. There have been several reports of insecticide resistance in *Culex quinquefasciatus* including from Zambia, Sudan and Zanzibar [82, 316, 317]. However, there is currently no resource available which synthesises this information.

Complete information on the susceptibility of sandflies to the range of insecticides used in vector control programmes is not known. Sandfly resistance to malathion and pyrethroids has been reported in Sudan, presumably due to use of these insecticides for malaria control [318]. With increasing use of insecticides for leishmaniasis control, resistance in these vectors should be monitored and resistance management strategies developed.

Use of temephos as part of the Onchocerciasis Control Programme in west Africa led to resistance (followed by development of resistance to chlorphoxim when the insecticide was switched) [222, 319]. Resistance in this species is currently being managed by a rotation of temephos, Bti, and permethrin, the insecticide usage being determined by the rate at which water is flowing in rivers forming the major breeding sites of these vectors.

DDT, pyrethroid and organophosphate resistance are very widespread in dengue vectors [320, 321]. There is a low likelihood of development of insecticide resistance in tsetse flies due to the long life span of the flies and production of small numbers of offspring.

## 8.8 Entomological data management

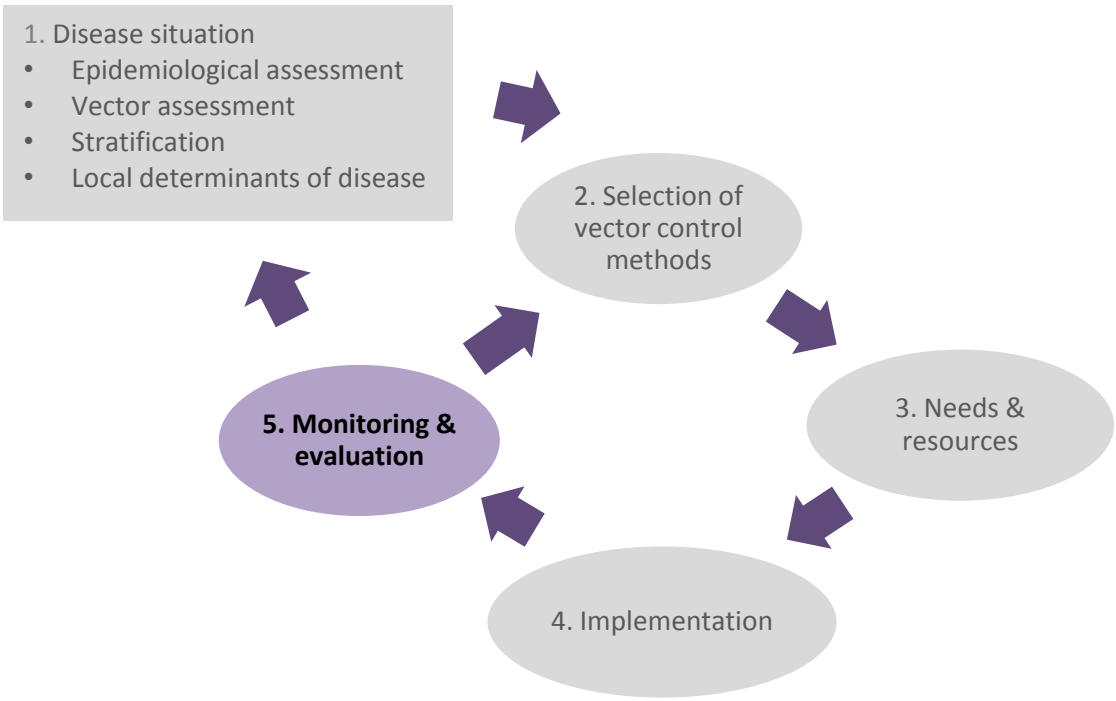
Entomological data should be collected on standardised forms. Data should be collated and reported from sentinel sites to district/provincial VBD control programmes in a timely manner.

To allow proper interpretation of data for decision-making, entomological data should integrated with epidemiological data (e.g. HMIS and surveys) and intervention coverage information. Data can be visualised in the form of maps. More information on integrated data management is given in 9.7. Data should be reviewed across VBD programmes because insecticide use in one VBD control programme may have unintended consequences on other vectors/diseases.

**CHAPTER SUMMARY**

- Vector surveillance should be conducted throughout the life of the IVM programme, although objectives and parameters measured will change depending on the stage of the programme.
- The most commonly measured parameter is vector density (mature or immature forms), although other parameters are important, particularly insecticide susceptibility.
- Sampling tools vary by vector, although there may be some overlap.
- When setting up sentinel sites there are a number of factors which should be considered including disease endemicity, ecological zones, accessibility of the site and use of insecticides in the area.
- Vector surveillance is usually conducted by vector control programme personnel, however, there are some good examples of community involvement in these activities.
- The presence and intensity of insecticide resistance in malaria vectors is increasing and so it is imperative to measure susceptibility on an ongoing basis in SSA. Insecticide resistance is also present in some other disease vectors, including culicines.
- Data management systems need to be established to manage and integrate the vast quantities of data generated on entomology, case surveillance, surveys and intervention coverage to allow for effective decision making.

# 9 Monitoring and evaluation




## 9.1 What is monitoring and evaluation?

Monitoring refers to the continuous tracking of programme performance and involves checking the progress against pre-determined objectives and targets. Monitoring allows you to verify whether activities have been implemented as planned, ensures accountability and detects any problems or constraints early in order to allow corrective action to be put in place. Monitoring focuses mainly on inputs and outputs.

Evaluation of outcomes and impact is needed to document periodically whether programme activities lead to expected results in terms of:

- Outcomes: for example, intervention coverage / usage or reduction in vector populations
- Impact: the assessment of impact, e.g. reduction in mortality or morbidity due to vector borne diseases (VBD).

Monitoring and evaluation (M&E) are interlinked. For example, monitoring will help you to identify possible weaknesses in implementation should the evaluation not show any impact of your programme. While monitoring is a continuous process, evaluation will need to be conducted intermittently. The periodicity of evaluation varies considerably according to the changes expected in the different areas evaluated.

A proposed M&E Framework including examples of illustrative data and example indicators for each of the domains (input → process → output → outcome → impact) is shown in Figure 9.1.

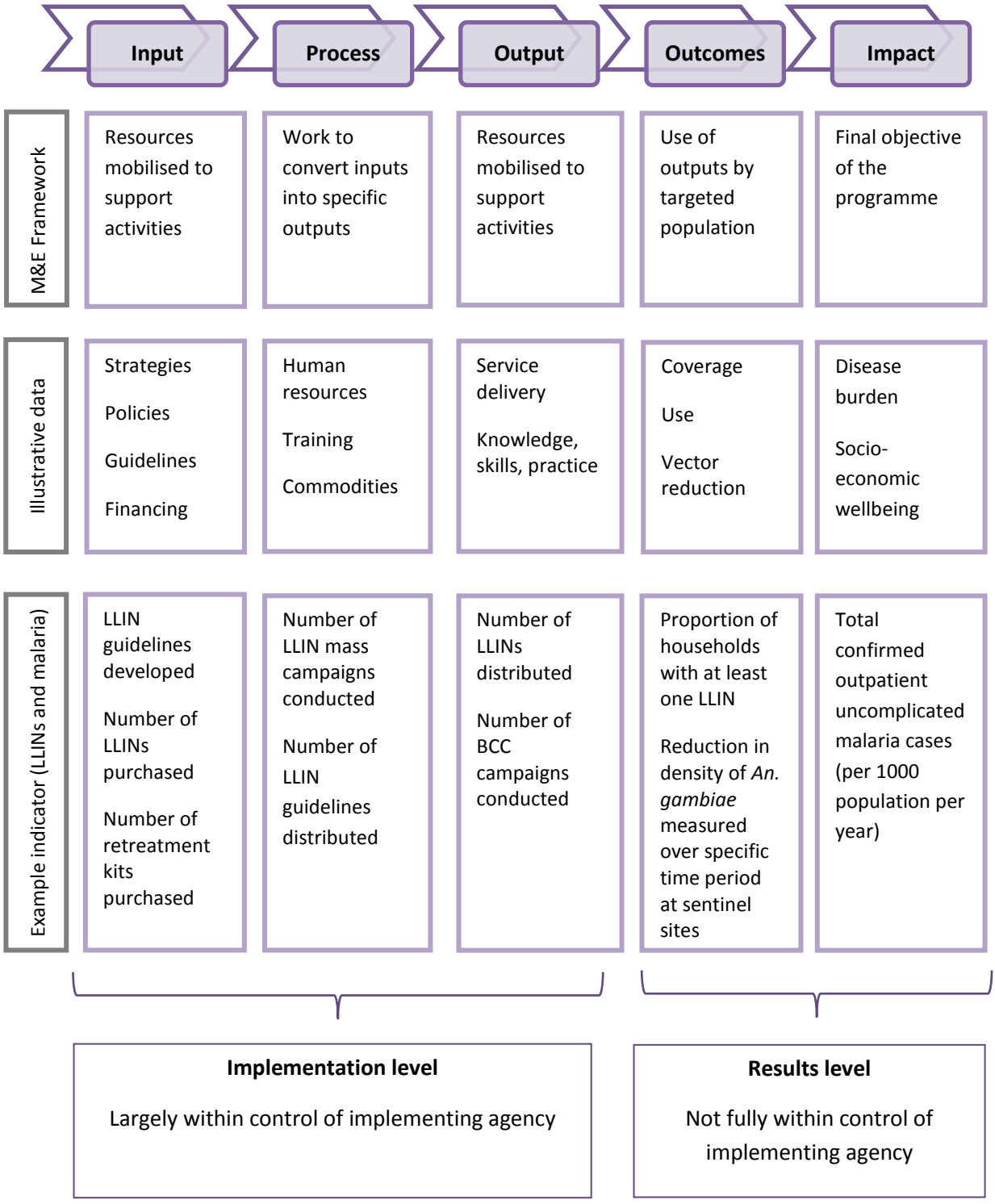



**Figure 9.1: M&E Framework for IVM programmes (adapted from [322])**
where LLIN = long-lasting insecticidal net

M&E of integrated vector management (IVM) is covered broadly in the WHO document on M&E Indicators for IVM [269]. More information on M&E of individual diseases can be found using sources listed in Table 9.1.

**Table 9.1: Sources of more information on M&E of VBD**

| Disease | Sources of more information |
|---|---|
| Malaria | RBM (2000) Framework for monitoring progress & evaluating outcomes and impact [323]<br>GFATM (2011) MONITORING AND EVALUATION TOOLKIT HIV, Tuberculosis, Malaria and Health and Community Systems Strengthening - Part 4: Malaria. [322]<br>MEASURE Evaluation – M&E Learning Center [324] |
| Lymphatic filariasis | WHO (2011) Lymphatic filariasis: monitoring and epidemiological assessment of mass drug administration programme. A manual for national elimination programmes. [325] |
| Cutaneous leishmaniasis | WHO - EMRO (2014). Manual for case management of cutaneous leishmaniasis in the WHO Eastern Mediterranean Region. [326] |
| Visceral leishmaniasis | WHO Regional Office for South East Asia / TDR (2010). Indicators for monitoring and evaluation of the kala-azar elimination programme - Kala-azar elimination in Bangladesh, India and Nepal. [327] |
| HAT | Bouchet B, et al. (1998). "Key indicators for the monitoring and evaluation of control programmes of human African trypanosomiasis due to Trypanosoma brucei gambiense." Trop Med Int Health. 3(6): 474-481. [328] |
| Dengue | WHO (2009). Dengue – Guidelines for diagnosis, treatment, prevention and control. [84] |
| Trachoma | WHO (2006). Trachoma control - A guide for programme managers. [329]<br>Emerson P, Frost L, et al. (2006). Implementing the SAFE Strategy for Trachoma Control - A Toolbox of Interventions for Promoting Facial Cleanliness and Environmental Improvement, The Carter Center / International Trachoma Initiative. [195]<br>Ngondi J, Reacher M, et al. (2009). "Trachoma survey methods: a literature review." Bulletin of the World Health Organization 87: 143-151. [330] |
| Onchocerciasis | No guidelines available for vector control M&E |
| Yellow fever | WHO (2008). WHO–recommended standards for surveillance of selected vaccine-preventable diseases. [331]<br>WHO (2008). Investigation of yellow fever epidemics in Africa - Field Guide. [284] |
| Chikungunya | WHO- PAHO (2011). Preparedness and Response for Chikungunya Virus Introduction in the Americas. [332] (No Africa specific guidance available) |
| Schistosomiasis | WHO (2006) Preventive chemotherapy in human helminthiasis. Coordinated use of anthelminthic drugs in control interventions: a manual for health professionals and programme managers [53] |

## 9.2 Responsibility for M&E and data flows

IVM works across diseases and therefore vector control programmes for different diseases should ideally be working from a single IVM M&E plan. Efforts should be made to convince donors of the need for cross disease control by submitting funding requests including more than one disease, where diseases are co-endemic. However, initially funding is likely to remain disease specific and so it is likely that M&E of the IVM programme will not replace M&E of the disease specific programmes.

Ownership of the IVM M&E plan remains with the country since this is for their use to assess their own IVM programme.

In monitoring and evaluating the IVM programme, the individual disease specific programmes are accountable to the IVM Focal Person at national level. At each level (district, province and national

level), the IVM focal person is responsible for collating data from individual VBD control programmes which fits into IVM M&E plan.

M&E data from district level is used to inform vector control activities on the ground. IVM should be based on local M&E data and therefore proper assessment and use of these data are essential. Data should be collated and fed to provincial level, who in turn report back to national level to give information on the impact of IVM. Often data are collated and analysed by the Central Statistics Office. The need for detailed data is generally lower at higher levels where a strategic overview becomes more imperative. Feedback loops should operate from national and provincial level VBD control programmes so that information once collated at national level is communicated back downstream.

Monitoring and evaluation conducted by an external agency, for example an academic institution is likely to increase accountability for vector control and help ensure unbiased results.

There are a number of users of information generated by M&E. These range from operational staff on the ground, to Programme Managers, the IVM Steering committee (ISC), country policy makers, international policy makers and donors. Data should be disseminated to the ISC and other stakeholders on a regular basis.

## 9.3 Choice of indicators

Indicators for M&E of IVM programmes are of 2 types - intervention/disease-specific and IVM programme-specific. Intervention/disease specific indicators are for example intervention distribution, coverage, changes in vector populations and impact on infection or disease. IVM programme specific indicators include process indicators on training of personnel on IVM and impact indicators on reductions in toxic units of insecticide used. Outcome and output indicators can be borrowed from disease specific log frames which programmes should already have in place.

How you are going to monitor and evaluate the programme should be detailed in an M&E plan which includes a logical framework or log frame. This should include expected reductions in indicators and expected impact of the programme. An example of a hypothetical log frame for monitoring an IVM programme tackling both malaria and lymphatic filariasis in a rural area using LLINs, IRS and LSM is shown in Appendix 3.

## 9.4 Evaluation design and attributing change

A number of different evaluation designs are available for evaluating your IVM programme. These vary in the strength with which you can attribute changes in impact indicators to the interventions in your programme. For example, randomised controlled trials or randomised step wedge designs are very robust and due to the randomisation process exclude the influence of other factors which may influence the outcome. Therefore we can say with reasonable certainty that changes which occurred are attributable to the programme. However, it is most likely that you will be using a longitudinal design (pre- post- comparison) without any control group. Here, other factors which influence the outcome may change over time and so attribution of effect is more difficult. When using longitudinal data on disease or infection to measure impact of your IVM programme, it is important to note (and where possible measure) external factors which may be influencing the

outcome. For example these external factors may include, parallel programmes initiated by a non-governmental organisation (NGO), changes in diagnosis and treatment practices or changes in weather conditions which may affect vector abundance.

## 9.5 Measuring Impact of IVM Programmes

There are 4 main impacts of an IVM programme that we are interested in: effect on disease burden, cost effectiveness, ecological soundness and sustainability of the programme. These impacts are outlined in Table 9.2.

**Table 9.2: IVM Impact indicators split by domain (adapted from [333])**

| Impact domain | | Indicators |
|---|---|---|
| Health | | Disease burden (number of cases/infections), mortality from disease, equity |
| Economic | | Cost effectiveness |
| Environmental | | Insecticide use |
| Sustainability | Social | Collective action, organisation, networking, community acceptability |
| | Institutional | Intersectoral collaboration, local involvement |
| | Political | Access to government, resource allocation, policy change, continued resource allocation |

### 9.5.1 Effect on disease burden

It is important to measure the effect of your programme on disease burden, including morbidity or mortality. A standardised definition of clinical disease (including diagnostic confirmation where possible) should be used to allow comparison across sites and between countries. Information on recommended case definitions can be found in the disease specific documents mentioned in Table 9.1.

Sources of data on infection and/or disease will vary depending on the country setting and the disease involved (Box 9.1).

**Box 9.1: Data sources for measuring effect on disease morbidity or mortality**

**Population based:** censuses, civil registration and vital statistics (deaths and causes of death), health management information system (HMIS), population-based surveys (DHS, MICS), active case detection strategies, Integrated Disease Surveillance and Response (IDSR) system

**Institution based:** Individual records (public and private health facilities), service records (public and private health facilities), resource records, school or employer absentee records, school or other institution-based surveys

**Others:** NGO data, agricultural records

Where the outcome of interest is death from the disease, it may be possible in some countries to gather this information from civil registration and vital statistics data.

Data on disease incidence can be obtained from health management information systems (HMIS), collated from public and private health facility records or from the Integrated Disease Surveillance and Response (IDSR) system, if the particular VBD is captured in this system [334]. Data are generally compiled either weekly or monthly at each health facility and then reported up a vertical chain, with further aggregation at each level in the health system (district then province) until reaching the most central level. Data collected in this way is known as passive case detection i.e. patients seek care at health facilities and cases are recorded by the health worker and reported to the appropriate epidemiological surveillance system. This system captures only a proportion of cases since access to health care is often limited, patients may not seek care and patients attending private health facilities are often missed. The passive case detection system is only as effective as the health system in which it is embedded. A number of aspects are important. For example, case reporting should be based on confirmed diagnosis as standard. High quality, complete data are necessary and data should be reported in a timely manner to higher levels of the health system to allow rapid action against focal VBD, in particular malaria and dengue. Support and supervision to quality control the surveillance system are also necessary. Despite these potential failings of a passive case detection system, epidemiological data collected in this way can still be used to measure trends. There are some excellent resources on disease surveillance for malaria control and elimination which could be drawn upon for other VBDs [335-337]. An example of malaria sentinel surveillance system in Ethiopia which relies on case reporting from a selected number of health facilities rather than the HMIS is given in Box 9.2.

**Box 9.2: Sentinel surveillance system to monitor malaria trends in Oromia Regional State, Ethiopia (adapted from [338])**

Ethiopia's National Malaria Control Strategic Plan includes goals to eliminate malaria transmission in low transmission areas and achieve zero malaria deaths by 2015. In order to plan interventions and monitor progress towards these goals, a robust surveillance system is necessary. This system in particular needs to be able to quickly identify changes in malaria transmission, morbidity and mortality and given the focal nature of malaria transmission in some areas of Ethiopia, identify transmission hot spots.

A system of 10 malaria sentinel sites was set up in Oromia Regional State, Ethiopia in 2010 to collect data on key malaria morbidity and mortality indicators. Ten primary health care units (PHCUs) were selected, each serving a catchment area of approximately 25,000 people and consisting of district (woreda) level health centres and associated satellite community (kebele) health posts.

Health centres are primarily located in urban areas and are usually staffed by health officers, lab technicians, pharmacists and midwives. Most have inpatient facilities and are the first referral point for severe malaria cases from the health posts. Health posts are located in rural areas and are staffed by health extension workers (HEW) who are salaried staff generally drawn from the communities which they serve. HEWs are able to diagnose malaria cases using a rapid diagnostic test (RDT) and provide artemisinin combination therapies (ACTs) to confirmed cases.

The following criteria for selecting sentinel PHCUs were decided during a national stakeholder meeting:

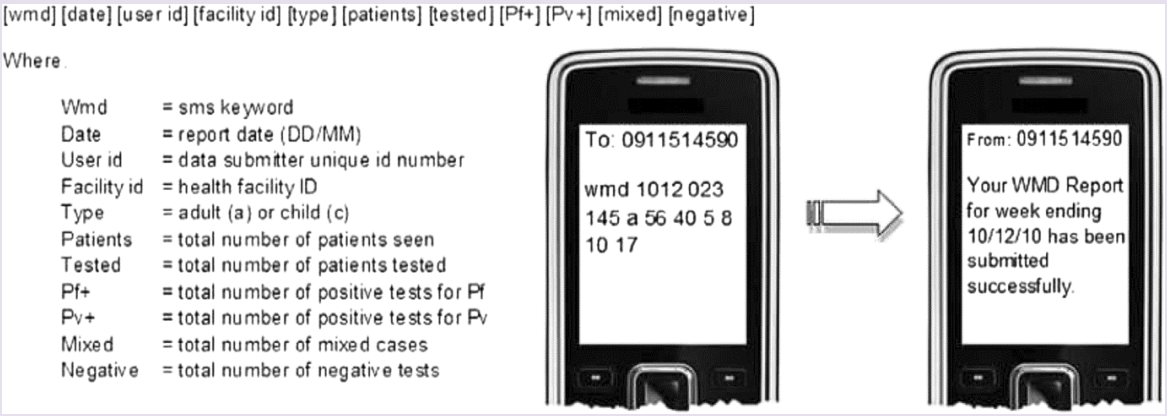
1) presence of an outpatient clinic that sees an average of at least 50 patients per day
2) laboratory capacity to diagnose malaria using microscopy

3) ability to provide ACT as first-line treatment for uncomplicated malaria during selection visit
4) pre-existing designated personnel responsible for data collection and reporting at the facility during selection visit
5) situated below 2,000 metres above sea level in a malaria transmission area
6) electricity available and year-round access via road.

Initially the health centres were the central focus of each sentinel site but over time the system was expanded and in 2012 (after ~ 2 years), data were being collected and reported from 10 health centres and their 73 satellite health posts.

At health centres, data were collected from an outpatient department (OPD) register and a laboratory register. The OPD register collected information on: patient age, location of residence, fever history, laboratory tests requested, laboratory results for malaria and relapsing fever (e.g. microscopy or RDT), species-specific final diagnosis (i.e., uncomplicated malaria, severe malaria, other), drugs prescribed, inpatient admittance, death and referral to higher level facilities. At health posts, data were collected from the routine fever and malaria patient register.

The sentinel facilities send aggregate weekly data through short message service (SMS) to a central database server.




*Screen shot of mobile phone displaying data reporting format used at the health post level.*

To reduce the potential for error, a number of logic checks are in place so that if numbers sent in by SMS from health facilities are implausible a message is sent indicating that resubmission is necessary. Once the SMS data is compiled on the central server web-based reports can be generated which allow users to view the data in near real-time for assessment of expected and actual malaria cases occurring within the defined area. Alerts can be set up so that managers as well as staff from the particular PHCU receive an SMS or email if the number of cases exceeds a predefined threshold value for that health facility.

For the purposes of quality control, surveillance field support staff visited health centres (initially every 2 weeks) and worked with staff to extract relevant malaria data from the registries. These data were considered gold standard and were compared to SMS data. Overall concordance between paper and SMS reporting was generally high and improved over time (~15 weeks).

The use of SMS for reporting surveillance data shows promise allowing accurate tracking of malaria trends in Oromia Regional State, Ethiopia. Small-scale sentinel surveillance with enhanced supervision and rapid reporting mechanisms are a viable alternative to relying solely on data collected through the country's routine HMIS.

Alternatively, active case detection strategies can be employed. This means that health workers visit communities and actively screen the population to find cases. Active case detection is useful when a disease is rare, occurs in isolated clusters, where patients do not present at health facilities (e.g. asymptomatic or stigmatised disease) or where you want to understand disease incidence in a specific sub-population. For example, lymphatic filariasis is normally identified through population-based surveys for microfilaraemia or antigenaemia [53]. Resources can be shared across VBD control programmes for conducting surveys. For example, lymphatic filariasis and onchocerciasis surveys could be conducted in tandem. More accurate estimates of malaria incidence or parasitaemia in children under 5 years old can be obtained by conducting population-based surveys. Examples of some active case detection techniques that have been used effectively for leishmaniasis are given in Box 9.3.

**Box 9.3: Active case detection strategies for measuring disease burden (adapted from [29])**

| | |
|---|---|
| House to house search: | Health workers visit houses and screen every household member for disease. |
| Camp approach: | Health workers set up a camp in a village e.g. central point or school and, after a community awareness campaign, community members are invited to attend the camp for screening. |
| Index case approach: | A positive (index) case is identified and then households nearby to the index case are screened for cases. |
| Incentive-based approach: | An incentive (monetary or otherwise) is given to health volunteers who facilitate case detection. |

### 9.5.2 Cost and cost effectiveness of IVM programmes versus standard practice

IVM is expected to be more cost effective than conventional vector control programmes because it reduces duplication across disease specific vector control programmes and evidence based use of a diverse range of vector control tools is likely to lead to more effective control. However, this needs to be systematically assessed by programmes and an increased evidence base on cost effectiveness of IVM versus conventional programmes will help to build the advocacy case for IVM.

The idea of cost effectiveness analysis is to assess whether we can prevent more mortality or morbidity at a lower cost by using IVM compared to conventional vector control. The first step should be to assess the cost of implementing your IVM programme and the cost of implementing routine vector control. In order to make sure you haven't missed out any costs you should adopt an 'ingredients approach' i.e. listing costs for different types of activity by category rather than just listing the total costs or total expenditures. For example, programme costs include capital costs (vehicles, equipment, buildings) and recurrent costs (personnel, operating expenditures, training, media campaigns and IEC). It is important to make sure you have included all costs, for example supporting interventions such as community engagement campaigns as well as the cost of the interventions themselves. Costing using the ingredients approach can be done using the open-source software Cost-It available on the WHO-CHOICE website [339].

The cost effectiveness of the IVM strategy is measured by looking at the cost of preventing a death or case of disease or infection (incidence or prevalence) compared to the conventional VBD control strategy (see Box 9.4).

**Box 9.4: A hypothetical example to illustrate cost effectiveness (cost per case averted) [adapted from [340]]**

A conventional malaria vector control programme in a district involving use of LLINs is being replaced by an IVM programme which involves LLINs, larviciding and drainage of surface water. We want to compare the cost effectiveness of the two programmes.

First we need to look at how the effective the programmes were in preventing malaria cases. Historically, before implementation of any vector control programmes there were on average 1500 malaria cases. Under the conventional vector control programme there were 1000 malaria cases in the district. However, once the IVM programme was introduced the number of malaria cases in the district fell to 500.

The next step is to look at the costs of the programmes. The conventional malaria vector control programme cost on average $25,000 per year, while the IVM programme cost $40,000 per year.

We can now calculate the cost per malaria case prevented:

| *Programme* | *Cost ($)* | *Malaria cases prevented* | *Cost per malaria case prevented ($)* |
|---|---|---|---|
| Conventional vector control programme | 25,000 | 1500 - 1000 = 500 | 25,000 / 500 = 50 |
| IVM programme | 40,000 | 1500 – 500 = 1000 | 40,000 / 1000 = 40 |

The IVM programme costs $40 per malaria case prevented compared to $50 for the conventional vector control programme. So, in conclusion we can say that the IVM programme is more cost effective than conventional vector control. Note that the IVM programme was actually more expensive than conventional vector control but being cheaper is not the same as being cost effective!

Although the simplified example in Box 9.4 only describes malaria, it is important to look at the impact of programmes on the number of disease cases or deaths occurring from all vector borne diseases in the area. For example, if an area is endemic for both malaria and lymphatic filariasis, the costs and benefits (cases or deaths averted) of the individual programmes should be compared to the costs and benefits of the combined IVM programme. When costing the IVM programme it is good practice to subtract any cost savings made through prevention of cases, for example inpatient treatment costs, although this information might be harder to obtain.

The comparison of costs and effectiveness between conventional vector control and the IVM programme can be of 2 kinds: i) before and after comparison (conventional vector control programme versus IVM programme) or ii) comparison between IVM programme area and another area concurrently implementing conventional vector control.

More information on how to perform a cost effectiveness analysis is available [341]

When looking at the cost effectiveness of an IVM programme in its early stages (for example in year 1 or 2 of implementation) we need to bear in mind that start-up costs are likely to be higher than long run costs of the programme and so the cost effectiveness of IVM may initially look poor compared to a long-standing conventional vector control programme. This phenomenon of high initial start-up costs but increasing cost effectiveness over time was observed in an analysis of environmental management and house modification for malaria control in copper mining communities in Zambia in the 1920s and 1930s [233].

### 9.5.3 Reducing insecticide use versus standard practice

Insecticide-based interventions such as LLINs and IRS are the mainstay of vector control for many VBDs. However, diversification of vector control tools used through IVM may help to reduce insecticide use thus reducing the risk of developing insecticide-resistant vectors, the impact of vector control on the environment and adverse effects on health. This can be systematically assessed by comparing the number of toxic units of insecticide used per disease case averted between standard vector control and the IVM programme. The toxic units of insecticide measure is used rather than simply the volume of insecticide because some insecticides may be more toxic than others. In order to measure this indicator it is important for programmes to keep good records of insecticides used. Further information on calculating the number of toxic units of insecticide used per disease case averted can be found in the WHO Monitoring & Evaluation Indicators for IVM booklet [269].

### 9.5.4 Sustainability of the IVM programme

Sustainability of the IVM programme can be measured in a number of ways. The WHO Indicators for M&E document recommends assessing whether there is a strategy in place to ensure continued mobilisation of resources for vector control [269]. To measure this indicator an interview or survey should be conducted with the relevant government bodies and a copy of the relevant strategy document obtained. The 'institutional memory' of VBD control programmes can also be assessed – for example are there standard operating procedures (SOPs) and training documents available to ensure the continuation of activities should key staff retire or leave the programme.

Programmes with greater resources may also be interested in the social, institutional or political impact of the programme since these are important aspects which will influence whether the IVM programme is sustained (Box 10.6). For example, community acceptability is a social impact of the programme – if interventions or the programme are not acceptable to the community then this will have a dramatic impact on programme success and sustainability. Measuring social, institutional or political impacts of the programme will require specialised quantitative and qualitative techniques. More information on social research methods is given in Box 9.5 and in further reading [342, 343]. Practical examples of where these types of techniques have been used to assess community participation and intersectoral action are given in Box 9.6, 9.7 and 9.8.

**Box 9.5: Social research methods for measuring social, institutional and political impacts of IVM programmes (adapted from [344, 345])**

Social research methods allow us to look at and understand aspects of programmes in greater depth. They help us to answer the 'How?' and 'Why?' questions. The methods most commonly used in monitoring and evaluation are:

**Focus groups**:

A group of approximately 8-10 individuals is brought together to discuss a particular topic for approximately 60-90 mins. The discussion is guided by a facilitator who normally has a topic guide (which lists down the topics they want to cover in the discussion) and guides the discussion by asking open-ended questions, for example "What is your opinion on the new vector control programme?". The discussion is either tape recorded or recorded by a dedicated note taker. It is important to consider the participants in a focus group since people will be more likely to interact well if they see other participants as being like themselves. Group interaction often means that data and insights are produced that might be less easily accessed in a one-to-one discussion.

**In-depth interviews**:

Interviews vary depending on how structured they are. In un-structured interviews the pace, subject and questions vary according to the interviewee. Structured and semi-structured interviews follow an interview guide consisting of a series of questions. In structured interviews, the interviewer asks questions strictly according to an interview guide so that every respondent is asked the exact same questions in the same order. More commonly used are semi-structured interviews where the interview guide is followed more loosely and the interviewer has freer rein to probe the respondent. Interviews can be conducted by telephone or in person.

**Observations:**

There are 2 main types of observation: participant observation and direct observation. In participant observation the observer becomes a member of the community or population they are trying to observe. The observer participates in activities and observes how people interact with each other and other organisations. Participant observation may be difficult in the context of a programme unless the observer is external. A more useful technique may be direct observation where the observer watches activities but does not participate in them. Their role can be covert (individuals being observed do not know the purpose and role of the observer) or overt (individuals being observed know the purpose and role of the observer). If the population being observed are aware of the role of the observer, bias can be introduced if they change their behaviour in response to this. This type of bias is known as the Hawthorn Effect.

**Document review**:

Programme documents such as policies, meeting minutes, correspondence and routine records on clients or services are a useful source of information on programme activities and processes and can help generate questions which can be answered using other qualitative methods. Document review has the advantage that you can review activities that have happened in the past and recall is not a problem since the documents were produced at the time of the event.

**Analysing Qualitative Data:**

Once you have qualitative data in hand whether this is from a focus group discussion or interview you should go through it to identify the main themes, see how often these themes appear in your data and think about how themes are related i.e. are there patterns developing?. There are specialised software packages which are available to help you organise and analyse your data, such as NVIVO, ATLAS.ti or EZ-text (downloadable for free from the CDC website: http://www.cdc-eztext.com/). It is often interesting to compare themes and patterns *between* groups or individuals. For example, a focus group held with farmers who according to new IVM policy have to dry their fields once a week may have different views on the programme compared to members of a community group.

**Survey research:**

The first step in survey research is to produce the survey. You should consider carefully the questions you want to ask, how you want to ask them and the order in which these questions should appear. Questions can be closed (requiring simple yes/no answers) or open-ended (requiring longer free-text answers). Surveys can be administered either in person using an interview or the respondent can fill out the questionnaire themselves. It is also important to consider how you will sample your respondents – this can be probability sampling (e.g. simple random sampling, systematic random sampling) or non-probability sampling (e.g. convenience sampling or purposive sampling).

**Box 9.6: Qualitative assessment of community-based vector control in Malindi, Kenya (adapted from [346])**

Community involvement plays a large role in the National Malaria Control Strategy in Kenya. The Municipal Council of Malindi has created an environmental and mosquito control activity mandate under the national Primary Health Care programme. Community groups, partly supported by government funds are responsible for environmental management tasks and implementation of malaria control activities. Community groups are involved with treating ditches, making and selling LLINs, draining stagnant water, organising clean ups, making and selling repellent neem soap and organising community campaigns such as the "Malaria Mosquito Day".

The study used key informant interviews, focus group discussions and a stakeholder meeting. The idea was to determine which malaria control activities community groups were involved with and identify successes and obstacles to successful implementation of vector control. Key informants from the Ministry of Health, Municipal Council of Malindi and the Ministry of Culture and Social Service, Gender and Sports were identified. These key informants were interviewed by facilitators trained in participatory techniques. A stakeholder meeting was held with representatives of community groups, NGOs, businesses and public offices responsible for organising vector control within Malindi. Focus groups were held with 8 community groups randomly selected from a total of 19 groups identified as having a role in mosquito control. The focus group discussions covered roles and responsibilities of community groups in vector control, operational constraints to effective control and challenges faced. Focus group discussions were led by a facilitator and there was a separate note taker. All discussions were recorded using a dictaphone as well. Information was transcribed and explored to generate categories and explanations using a thematic framework. Data collected using the three different methods were compared to see if similar themes were emerging.

A number of challenges were identified which are potential barriers to sustainability of the community based vector control. For example, support from the municipal council was identified as an important enabler. Prior to 1999 a high degree of municipal support was provided in terms of training and guidance, equipment, monitoring and supervision and regularity of control activities declined following withdrawal of this support. Community groups reported that this support and supervision was a motivating factor and made them feel recognised and appreciated. Another barrier identified was that projects did not generate sustainable income (e.g. ITN manufacturing and sales community group) and that volunteerism could not be sustained in the absence of income generation when the community group members themselves were poor.

**Box 9.7: Measuring and evaluating intersectoral action (adapted from [347])**

Intersectoral action is one of the key aspects of an IVM programme whereby actors and organisations from different sectors come together to take action against VBD. It is therefore important to assess how intersectoral action is working and to learn from experience.

The materials used by the WHO when generating case studies on intersectoral action to tackle social determinants of health provide some excellent guidance on describing and assessing intersectoral action.

Some important questions are outlined below.

**APPROACHES:**

What mechanisms and tools were used to support intersectoral action? For example:

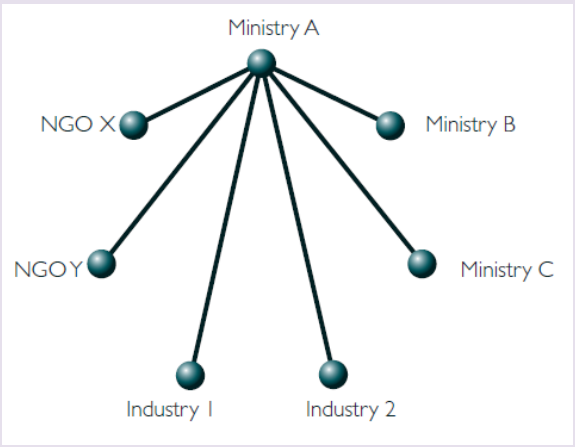
- information e.g. research, knowledge transfer, communication, evaluation results
- institutional arrangements or mechanisms e.g. National Commission
- financial mechanisms e.g. source of funding, budgeting structure
- legislation and regulation
- accountability frameworks or monitoring mechanisms
- planning and priority setting

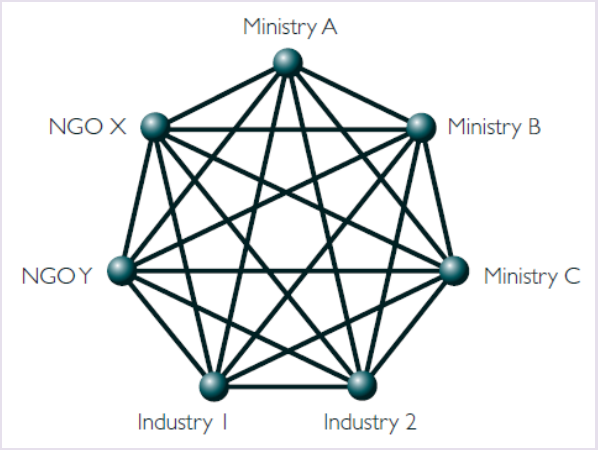
What are the architectural arrangements of the intersectoral action / programme / policies? For example:

- Who were the principal actors responsible for influencing the policy decision, its implementation and evaluation? What role did they play? NB: this role can be beneficial or non-beneficial!
- What was the role of the health system/sector in terms of leadership, coordination etc?
- What is the best descriptor of the level of integration? See Box 10.9 for categories of integration.
- Were there participatory mechanisms involved? What were these mechanisms? Who participates and what are their motivations? Participation can be categorised as follows:

| Score | Classification | Explanation |
|---|---|---|
| 0 | Informing | To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions |
| 1 | Consulting | To obtain public feedback on analysis, alternatives and/or decisions |
| 2 | Involving | To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered |
| 3 | Collaborating | To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution |
| 4 | Empowering | To place final decision-making in the hands of the public |

- What was the model of the relationship? Examples of models illustrating the relationships are shown below. Informal relationships could be depicted using dotted lines.




- Were there budgeting and financing mechanisms that promote intersectoral action? What were these mechanisms e.g. funding pools? Which sector or entity proposed the mechanism and how was it set up?

**IMPACT AND LESSONS LEARNT**

- What were the actor's responses to the process and outcomes, given their expectations?
- How did the perspective of the health sector or other sectors change?
- Did concerns about VBD become a stronger issue within the public, other sectors or the government due to this initiative?
- What is the impact/role of data/evidence on VBD in stimulating action?
- Which structures, mechanisms, platforms and incentives work well or poorly, and why?
- How could implementation have been improved?
- How can specific barriers be overcome, including those related to funding/budgets, personnel and skills mix etc.

**Box 9.8: Example of measuring intersectoral action for malaria control in Ghana (adapted from [348]**

An example of a simple method for assessing intersectoral action is provided by Owusu *et al.* (2013) who examined the degree and determinants of intersectoral action among organisations working in malaria control in two districts of Ghana (one urban and one rural). The researchers interviewed representatives from 32 core institutions (16 from each district) engaged in malaria control in Kumasi metropolis and Ahafo Ano South district, including institutions from the health sector, agriculture, education, environment, economic/finance sectors and community groups. Institutions were selected based on a document review and consultation with representatives from the Ghana Health Service who oversee the implementation of health policies and programmes in Ghana. The types of personnel interviewed included service providers, administrators, service users/community members (including local politicians).

The researchers used a simple classification for the different levels of intersectoral collaboration:

| Score | Classification | Explanation |
|---|---|---|
| 0 | Non-awareness | Institution has no knowledge of another institution's malaria programmes |
| 1 | Awareness | Institution has knowledge of another institution's malaria control programmes, but does not participate in their activities |
| 2 | Communication | Institution has knowledge of another institution's malaria programmes and they only share information on their activities |
| 3 | Cooperation | Institution has knowledge of another institution's malaria programmes and not only shares information, but also shares ideas to guide and modify their own planning and activities |
| 4 | Collaboration | Institution has knowledge of another institution's malaria control programmes, they share both information and ideas and also jointly plan and modify delivery of service based on mutual consent |

The representatives from each institution were asked to rate their level of integration with the other institutions according to this scale and the results were inputted into a matrix. This allowed the authors to compare how well each institution thought they integrated with other institutions (self-reported depth of integration) and the how well other members of the network thought the institution integrated (group-reported depth of integration).

## 9.6 A quality assurance framework for IVM

Quality assurance (QA) is the implementation of systematic and well planned activities to prevent sub-standard services or products. Although this approach is commonly used in the manufacturing and other commercial industries, until now QA has not been well defined in the context of vector control. However, increasing pressure for greater accountability from donors and other stakeholders is prompting disease control and elimination programmes to move toward more formal and transparent methods of communicating: service quality standards; the methods by which the probability of a successful programme outcome are increased; methods for performing monitoring

checks and assigning quality scores to assess programme performance, and standardised protocols that delineate how problems are identified and the feedback loops in place to effectively correct them.

Good QA is a proactive approach which aims to maximize resources to increase the likelihood of programme success. Resources are valuable and sub-optimal quality outcomes and lack of impact can be traced back to an absence of quality assurance during the input, process and output phases of the programme. If planned outcomes and impact are or are not achieved the QA approach ensures that the strategic and operational levels of a programme have sufficient information to either support the current strategy or make necessary changes. This type of structured approach of identifying strengths and weaknesses in the different programme stages can lead to innovative ways of dealing with challenges upfront and avoid the potentially devastating consequences of poor vector control management.

**Figure 9.2: Quality assurance of indoor residual spraying: filter paper on the wall used for measuring insecticide application** (photo courtesy of S. Lindsay)

The success of an IVM approach is largely dependent on quality assurance of individual interventions alone and in combination. Implementing multiple interventions without knowledge of the effectiveness of single interventions when properly performed is not necessarily a cost effective choice leading to better impact, and managers and stakeholders at strategic and operational levels should drive the QA agenda in order to gather this knowledge to support effective IVM. Risk communities who are the primary beneficiaries should be consulted to understand their expectations.

Planning quality insurance for an IVM approach starts at a strategic level with the development of a quality assurance framework (QAF) document followed by operational guiding documents (QAG) (Figure 9.3).

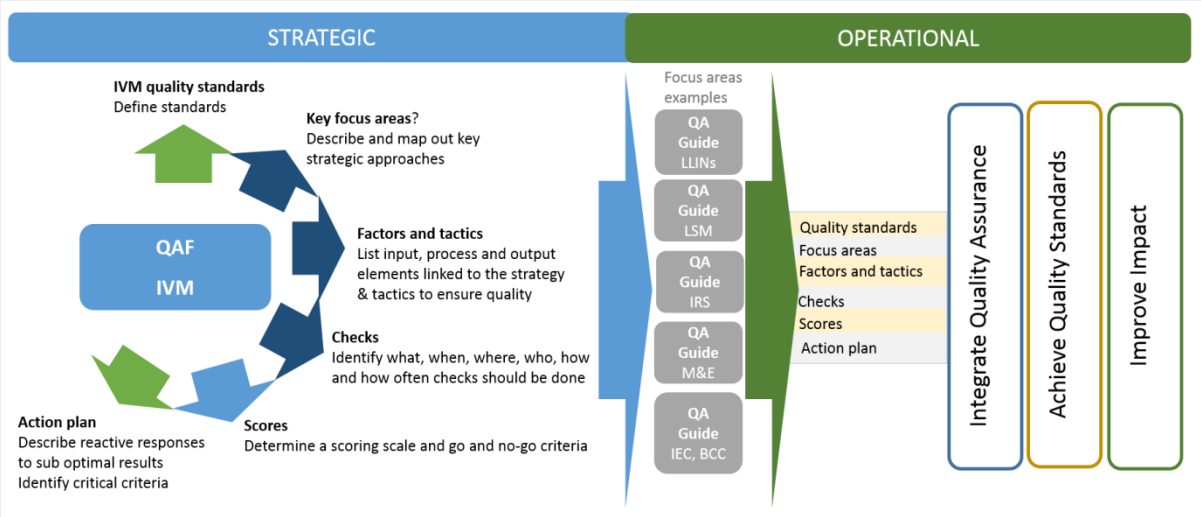



**Figure 9.3: Quality assurance planning at strategic and operational levels.**

The QAF aims to strategically define the quality of IVM, describes the methods to ensure this quality throughout the process/system as well as action plans. From the QAF more detailed guidelines (QAG) will follow to assist with the breakdown of detail and facilitate operational implementation.

Figure 9.4 is an extract of an example of a QA guide showing one IRS quality standard (>80 % room coverage), advocacy as an example focus area related to this standard, input, process and output factors associated with success or failure, tactics to minimize risk of failure, checks and scoring and the corrective action proposed if required.

Many vector control programme objectives, activities, indicators and targets will feed into a QA framework and guide. Duplication of efforts should be prevented and it is advised that a dedicated person take on the responsibility to ensure that a QA framework is developed and QA guides are implemented.

| IRS standards | Focus areas | Factors | Tactic | Checks | Score | Action |
|---|---|---|---|---|---|---|
| >80 % room coverage | IRS advocacy | **Input**<br>Funding<br>Personnel<br>Transport<br>Equipment<br>Timing<br>Tools<br>Etc. | Annual planning<br>Budget<br>Operational plan<br><br>Meetings and formal agreements | Adequate budget for personnel, equipment, materials and tools.<br>*Programme Manager.*<br>Annually - April<br><br>Advocacy plan finalized<br>Formal agreement with health promotion section to share transport.<br>*Programme Manager.*<br>Annually - April.<br>Follow up meetings<br>June, August<br><br>Meetings with community leaders in each village.<br>*District Vector Control Programme Managers* - August<br><br>Health promotion materials available.<br>Vector Control Programme *Procurement Officer* - July<br><br>Equipment tested and available.<br>*District vector control programme manager assistant*<br>-July | Green (no action), orange (action) or red (no go).<br><br>This is for all scores. | If budget was not approved, discuss possible sharing of further resources with other sections within the health system<br><br>Determine reasons.<br>Emergency workshop and meetings to facilitate plan and agreements<br><br>Determine reasons.<br>If time constraints bring all community leaders to one venue.<br><br>Determine reasons.<br>Decide on alternatives and contact other sections or departments for assistance<br><br>Faulty equipment requires immediate fixing or alternative arrangements to borrow equipment from other sections or departments. |
| | | **Process**<br>Acceptance<br>Understanding | Survey | 90% will agree spray operators to enter their house<br><br>90% understand why IRS is important | | Determine reasons for low scores.<br><br>Rectify where possible e.g. revise all materials and tools for the next season.<br><br>Emergency community meetings. |
| | | **Output**<br>Communities reached | Survey | 100% of all targeted communities reached. | | Visit communities not reached.<br><br>Determine reason for low numbers. |

**Figure 9.4: Example of a section within QA guidelines for IRS, expanding on IRS advocacy as a focus area to achieve good room coverage.**

## 9.7 Data management for M&E

Disease and vector surveillance will produce a vast quantity of data for the monitoring and evaluation of a programme. Data needs to be integrated on entomology, epidemiology, interventions and other factors such as meteorological information. In order for these data to be used to their full advantage for donor reporting, measuring progress and impact and evidence-based decision making it is important to establish a data management system (Figure 9.5). Outputs of the system such as results of queries e.g. what was the coverage of LLINs in district X during the last universal coverage campaign and reports and also potentially maps if the programme has GIS capability. These outputs can be used be operational staff and programme managers to trouble-shoot, adapt and problem solve. They can also be used to advocate to policy makers and for reporting to funders.

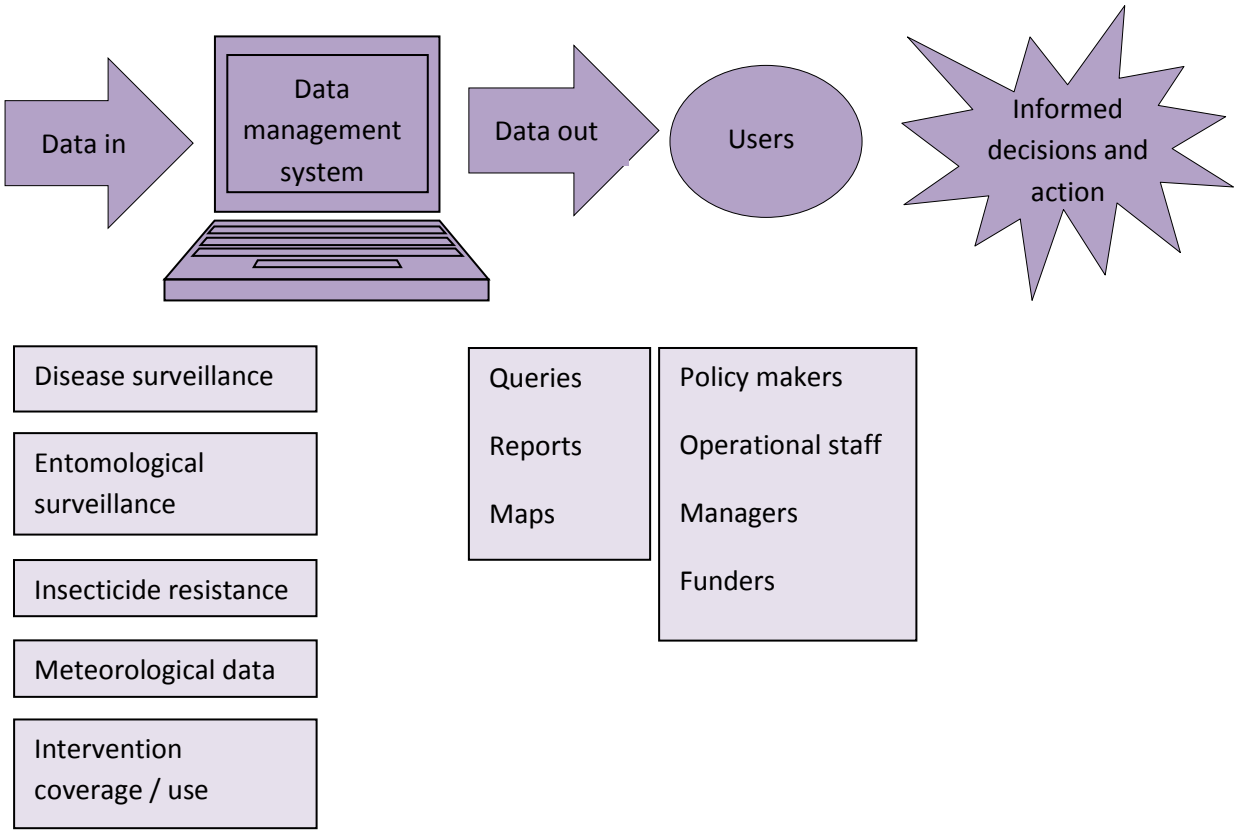



**Figure 9.5: Schematic showing integration of data using a data management system**

An excellent summary of the setup of a health management information system (HMIS) is provided in the document: WHO Western Pacific Region (2004) Developing health management information systems: a practical guide for developing countries [349]. While this handbook is geared towards case data and the EPI system, many of the concepts are valid for vector control programmes and are summarised below.

The first step is to consider the role of users in the hierarchy (Table 9.3) and the indicators they need to perform their function.

**Table 9.3: Function of programme entity by administrative level**

| Administrative level | Function |
|---|---|
| Village | Case finding, service delivery, entomological surveillance, IEC and BCC, outbreak identification and response |
| District | Monitoring (case management, entomology, interventions) and supervision, operational planning, outbreak identification |
| Province | Evaluation, strategic planning (where appropriate), programme planning |
| National | Policy formulation, strategic planning |

The data collected and reported in the data management system should tie in with the indicators you are interested in for monitoring and evaluation of the IVM programme. Looking at these indicators you should consider the source of information for the numerator and denominator and the frequency of data collection. For example, for an LLIN universal coverage campaign coverage indicator you need to know is the number of vouchers distributed during the enumeration process (denominator) and how many LLIN were distributed (vouchers redeemed - numerator). In another example, to measure disease incidence in a district you need to know the number of cases presenting at district health centres (numerator) and the corresponding district population (census - denominator).

Not all data needs will be met by the routine system of data collection, as mentioned above. There may be a need to do specific surveys for data required less frequently or required for only certain subsets of the population.

It is important to consider the lowest level where computers will be used for data management. This depends on budget, technical ability of the staff entering the data, technical assistance available for system maintenance, data security and compatibility of software with existing hardware.

Data collection and processing at lower levels is usually paper based although this may vary depending on the setting. For example, field data collection can be paper based or in some cases control programmes may issue personal digital assistants (PDAs) or smart phones for electronic data collection. Data collection tools need to be designed carefully and piloted before roll out. It is important to keep tools simple! Data consolidation and management at district, province and national should ideally be computerised. The data management system should ideally be overseen by staff with technical expertise with access to equipment such as computers and appropriate software.

Data will need to be recorded and managed so that it flows from the periphery to the central level and then aggregated data needs to be fed back to provinces/district/local levels. For example, data collection from individual sampling sites by field entomologists may be summarised in weekly reports by the district manager who reports to the provincial level authorities. The provincial level authorities will report to national level managers on a perhaps monthly basis. In addition, there may be non-health sector users and suppliers of data in this hierarchy. For example, data on insecticide use in the agricultural sector should be provided by the Ministry of Agriculture and assessed alongside insecticide resistance data in disease vectors.

The frequency at which data is reported to the next hierarchical level depends on the needs of the user and how often the phenomenon is observed e.g. weekly reports on larval abundance or a report on a LLIN coverage survey conducted yearly needs to be reported on a yearly basis. As the data moves up the hierarchy it becomes more and more summarised so that a good overview can be obtained. The most detailed data should be kept at the source level and reporting requirements should be kept to a minimum [349].

It is important to conduct training so that data collection and management is of a high standard. Training should cover completion of forms, computer input, data analysis, interpretation and utilisation [349].

When thinking about dissemination of the data it is important to consider the users of the data, what information should be disseminated, how often it should be disseminated and in what format, for example a written report, formal meeting or other mode of communication (Table 9.4).

**Table 9.4: Example of data dissemination activities** (Adapted from [349])

| Example of report/ activity | To whom it needs to be disseminated | Mode of dissemination | Frequency of dissemination |
|---|---|---|---|
| Annual malaria report | Government Statistics Office<br>Secretary of Health<br>Malaria control programme managers and staff (including province and district)<br>Implementing partners e.g. NGOs<br>Donor representatives | Publication<br>Dissemination meeting | Annual |
| Malaria incidence by province | National malaria control programme staff<br>Health facilities<br>Implementing partners e.g. NGOs | Telephone<br>Email | Monthly |
| District entomology field team meeting | Field technicians<br>District entomologist | Meeting | Weekly |
| Intervention team meeting | Sub-district supervisors<br>Technicians | Meeting | Weekly (for IRS and time limited LLIN campaigns) |

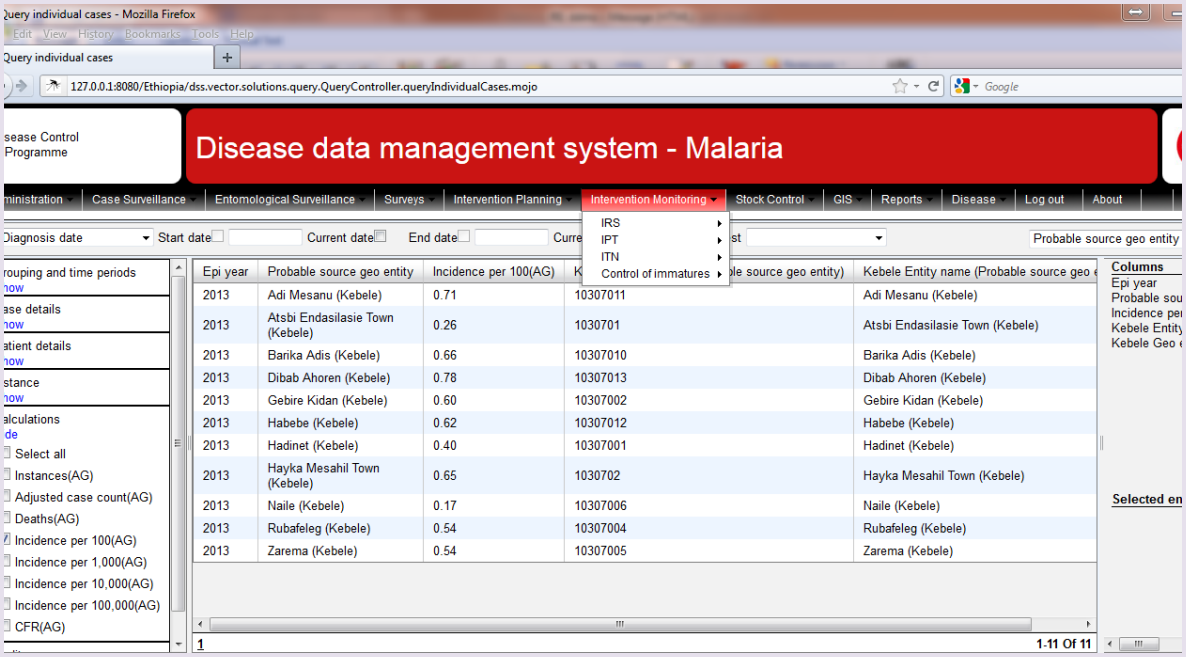
At each level (district, province, national) data should be assessed, interpreted and there should be a feedback loop to inform operational activities. Motivation of data producers is key to ensuring sustainability of the data management system and ensuring that high quality data is produced. Motivation can be increased by providing regular feedback (positive and negative) on data outputs.

An example of a computerised disease data management system which is able to integrate data on entomology, case reports, surveys and intervention coverage is outlined in Box 9.9.

**Box 9.9: Example of a data management system – IVCC Disease data management system**

The Innovative Vector Control Consortium (IVCC) has produced a Disease Data Management System (DDMS) which facilitates monitoring and evaluation (M&E) of VBD control programmes. Currently the DDMS supports M&E of malaria, dengue and visceral leishmaniasis, but allows the addition of other vector-borne diseases as well. The system has been fully road-tested and is being used by a number of programmes including malaria control programmes in Bioko Island, Zambia and Ethiopia and the visceral leishmaniasis control programme in India.

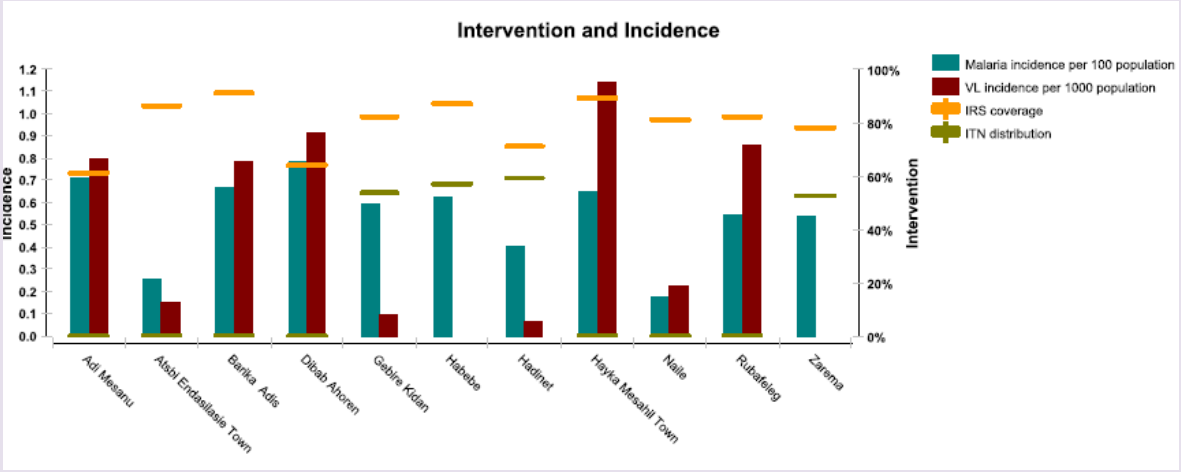
The DDMS uses open-source software which can be installed on a central server and accessed via an internet browser from remote computers. It is a modular system comprising individual modules capturing information on case surveillance, entomological surveillance, survey data (for example from malaria indicator surveys) and intervention monitoring. It also has modules which can be used for intervention planning and stock control. Data can be inputted into the system either directly or imported - a facility which is useful should a programme have historical data or if control programme staff are generating data in a different format or if they don't have online access to the DDMS.

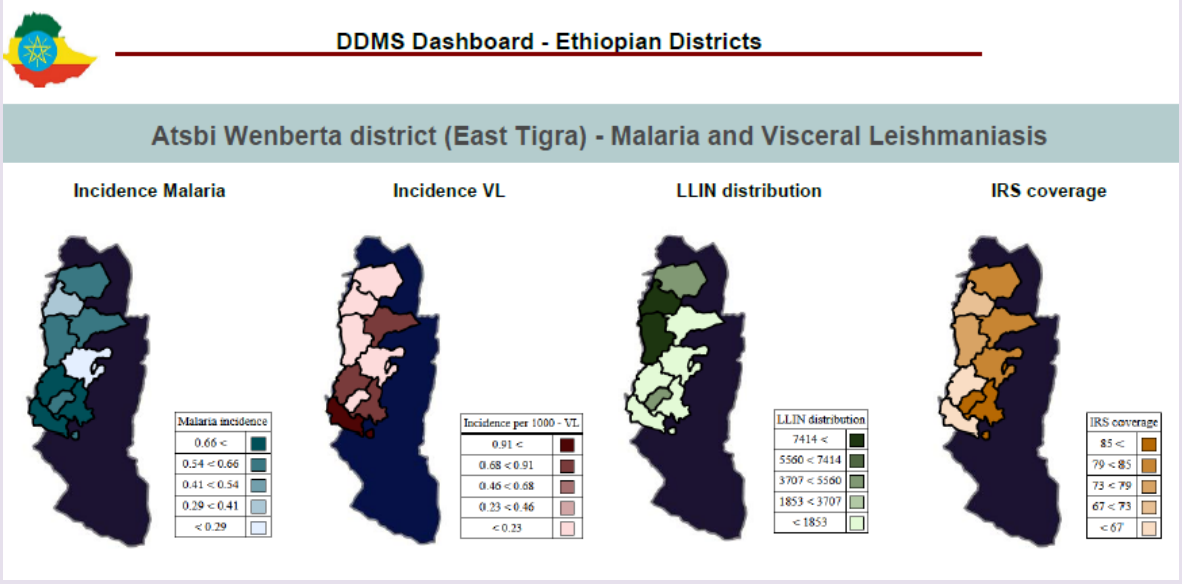



*Screenshot of DDMS interface and query builder (NB: Data is fictitious)*

The DDMS is also able to support decision making. The data can be queried and reports generated easily, with clear visuals including graphs and maps. Reports generated online are interactive and so it is possible to drill-down to the underlying data. Maps can be used to show differences in intervention coverage, entomological indictors or clinical cases by geographic area and can display either polygons or individual point data, for example larval abundance at sampling sites where these have been geo-located using a GPS. In addition, thresholds can be entered into the system to automatically flag and generate email alerts if, for example, there is an increase in cases in an area that would indicate early signs of an epidemic.

The system has been developed by Liverpool School of Tropical Medicine (LSTM) and IVCC and the team is able to provide training and technical support. However, full country ownership of the system is preferred and it is possible to train up a technically savvy country programme staff member in several weeks that would then be able to administer and run the system in country with little additional support.




*Screenshot of reports showing multi-disease capability (NB: Data used to generate these reports is fictitious)*

## 9.8 Making change, continue or stop decisions

As noted previously, VBD dynamics and programme goals (e.g. control versus elimination) will change over time and so the IVM programme will also need to change in time. Decisions on changing, continuing or stopping with a selected IVM tool should be based on thorough evaluation by the ISC who can advise the relevant departments. These decisions need to be made after assessing the effect of the intervention on epidemiological and entomological outcomes, along with

information on a number of parameters including cost, cost effectiveness, human resources and feasibility. It is also important to consider the receptivity and vulnerability of area to disease transmission before scaling back interventions.

**CHAPTER SUMMARY**

- Monitoring refers to the continuous tracking of programme performance and involves checking the progress against pre-determined objectives and targets.
- Evaluation of outcomes and impact is used to determine whether programme activities were successful.
- Disease specific programmes are likely to have their own monitoring and evaluation plans but these data should be collated into an IVM specific plan which covers intervention/disease-specific indicators and IVM programme-specific indicators (e.g. cost effectiveness, sustainability, intersectoral collaboration etc.).
- Vector control activities under IVM should have a quality assurance framework.
- Data management for monitoring and evaluation is hugely important and it should integrate data on disease surveillance, entomological surveillance, meterological information, and intervention coverage/use.
- Change, continue or stop decisions on vector control should be made based on through evaluation.

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## Appendix 1: Tool for stakeholder analysis (adapted from [350])

**Step 1: Identify key stakeholders**

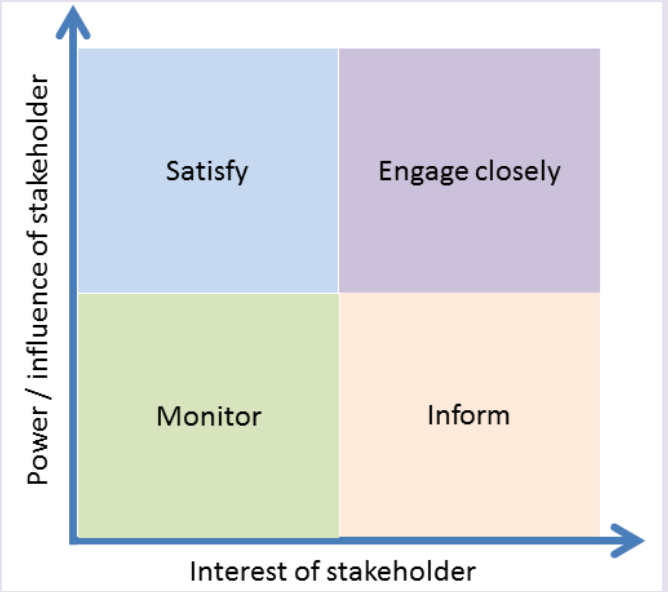
The first step is to brainstorm who your key stakeholders are in the IVM programme. A stakeholder is a person or organisation that has something to lose or gain from a project. They can be people who are affected by the programme, those who have influence or power over it or have an interest in its successful or unsuccessful conclusion.

**Step 2: List key characteristics of stakeholders**

The characteristics of each stakeholder should be detailed – in particular the name of the specific person in the organisation/group you are dealing with and the role of the stakeholder.

**Step 3: Prioritise your stakeholders**

Prioritise your stakeholders by considering their power/influence over the programme and their level of interest. The matrix shown below will help you to think this through. The power and level of interest of the stakeholders should influence the action taken with regards to this stakeholder. For example, powerful and important stakeholders should be engaged closely, while stakeholders with less power and importance may only need to be monitored.




**Step 4: Understand your stakeholders**

The next step is to brainstorm what you know about your stakeholders. How do they feel about the IVM programme? What motivates them e.g. emotion, finance? Who or what influences their opinion of the IVM programme? Is their opinion based on good information? What is the best method of communicating and engaging with them? What resources do they have? How will you gain their support of the IVM programme or manage their opposition?

**Step 5: Develop a plan of action**

Finally you should develop a plan of action with regards to your stakeholders. You should document the actions taken, who will be responsible for the action and by when/with what regularity.

An example of a fictitious stakeholder analysis for an IVM programme which is expanding to include drain rebuilding and maintenance is given below:

| Stakeholder | Person | Role | Power/ influence | Interest | Action taken | Responsible | Timeline |
|---|---|---|---|---|---|---|---|
| Ministry of Health | | Delivering health services | | | | | |
| Ministry of Finance | Mr. Ali | Determining level of financial support to other govt. ministries | High | Low | Lobby for increased funding for Ministry of Public Works | IVM focal person and VBD programme managers | August |
| Ministry of Public Works | Mr. Abass | Building and maintenance of drains | High | High | Lobby and educate on health benefits of filling and drainage. Ensure filling, drain rebuilding and maintenance is prioritised and conducted in areas with high VBD incidence. | | |
| Community leaders | Shehia leaders | Mobilising community support | High | Low | Engage community leaders to promote health benefits of clean environment | District level NMCP Vector Control Head | |
| Community group | Kigogo womans group | Involved in regular 'clean up' days | Low | High | Encourage more regular clean up days, provide support to clean up days, including promoting health benefits and mass media. | | |
| Private sector refuse collectors | | Refuse collection for a fee | Low | High | Encourage refuse collectors to look for opportunities to make money from garbage disposal and recycling. | District level IVM focal person | |
| Landlords | NA | Responsible for upkeep of housing / collect rent from tenants | Low | Low | No action. | - | - |
| Tenants | NA | Tenants | Low | Low | Ensure tenants are being reached through community education. | | |
| Tax department | Mr. Msellem | Responsible for tax collection | High | Low | Lobby for more efficient tax collection | | |

# Appendix 2: Local determinants of disease

## Introduction

The presence of Vector Borne Diseases (VBDs) depends on a complex interaction between pathogens, vectors, humans (animals in some cases) and the environment (Figure A2.1). It is important to consider these determinants and their interaction to understand why diseases occur and point to ways in which to control them. As a consequence of the interaction between these determinants, diseases can vary markedly in time and space. Some diseases such as malaria may be more stable in their geographic distribution over time, while others such as dengue may be patchier in their distribution and vary from year to year. Diseases may also be unequally distributed within the population because some individuals or communities may be more at risk of disease than others. Typically, 80% of the disease burden is experienced by 20% of the population [351]. For example, in malaria endemic areas people sleeping close to breeding sites will tend to have a higher risk of exposure.

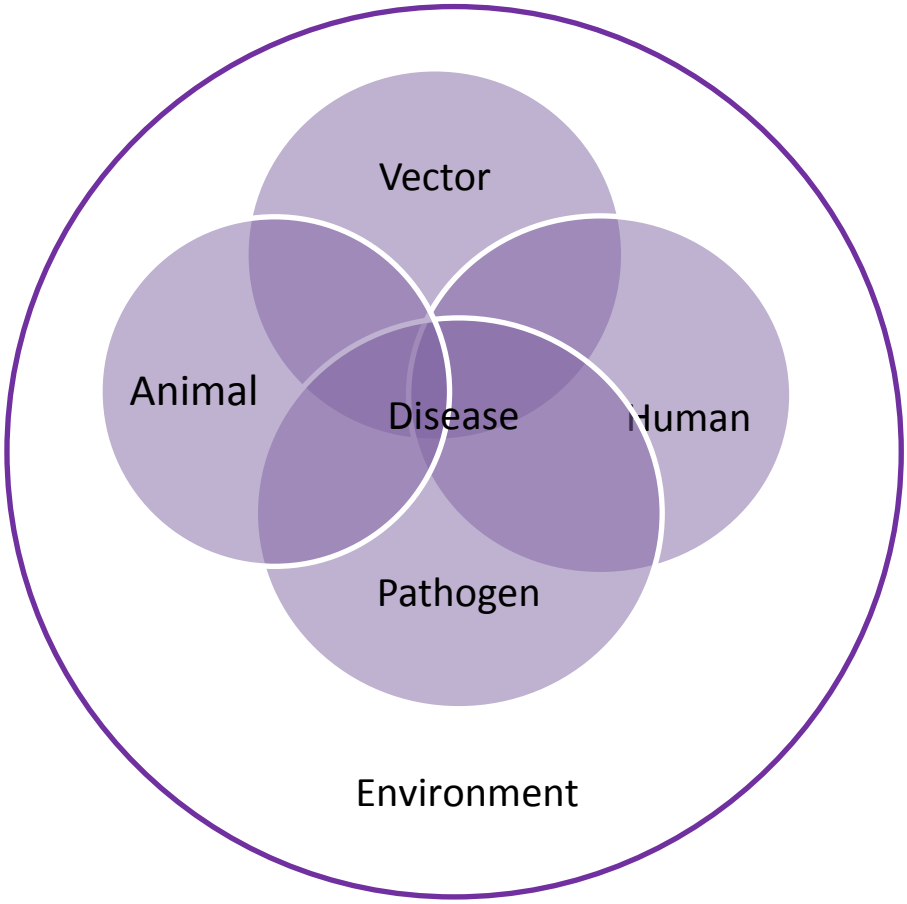



**Figure A2.1: The pathogen, vector, human, animals and environment depicted as five categories of determinants of vector-borne disease**

It is important to recognise that many determinants of disease are outside the scope and jurisdiction of conventional programmes for VBD control, such as irrigation systems, urban development, sanitation, and housing. These determinants are still extremely important and call for coordinated action with other sectors and local communities.

## Pathogen-related determinants

The first step is to consider which parasites or pathogens cause disease and identify where VBDs are endemic in your area. It is also important to consider medical options available for prevention (e.g., vaccines or preventive chemotherapy) or treatment of the disease. Some questions for consideration are outlined in Table A2.1.

**Table A2.1 Identifying pathogen-related determinants of disease**

| Question | Rationale |
|---|---|
| Which VBD are endemic in your area and are VBD co-endemic? | A central tenet of IVM is to use evidence to plan and implement vector control. Maps provided in this Toolkit provide an indication of what diseases are present and how they are distributed. This should be supplemented with collection and analysis of epidemiological data to prioritise VBD control at lower levels. |
| What medical options are available for disease prevention? | Vaccines and preventive chemotherapy are available for some VBDs. A vaccine is available for yellow fever (although this is mainly for travellers and may be out of reach for most residents of endemic countries) and vaccines are in development for some other diseases. Preventive chemotherapy is the mainstay of control for a number of VBDs including onchocerciasis and lymphatic filariasis. For malaria, intermittent preventive treatment of malaria in pregnancy using sulphadoxine-pyrimethamine (IPTp-SP) is recommended by the WHO in areas of moderate-to-high transmission [352]. The WHO also recommends the use of seasonal malaria chemoprevention in children aged 3-59 months in areas of highly seasonal malaria transmission across the Sahel sub-region [353]. |
| Which parasites or pathogens cause disease? | Diagnostic capability to distinguish between parasites<br>Falciparum versus vivax<br>Co-infection within an individual e.g. leishmaniasis and HIV |
| What medical options are available for treatment? | For some diseases, effective treatment is available and WHO guidelines on choice of drug and dosing should be followed. Where drug treatment is available, vector control programmes should also have an awareness of whether drug resistance is developing or where counterfeit or sub-standard drugs are a problem.<br>For some diseases, effective drug treatment is not available and only supportive care is provided e.g. dengue fever. |

## Vector–related determinants

It is important to identify the dominant vectors of VBD in your area. Vector distribution maps presented in this Toolkit will be of use here, but should also be supplemented by data collected in-country, for example vector surveillance data from sentinel sites. Identifying the relative abundance of vectors present in an area should be considered an ongoing activity since vector populations are rarely constant and new vector species may be introduced into your area e.g. *Aedes albopictus* - an efficient vector of chikungunya. Here are a few questions than can be asked to gain key information on vectors in your country (Table A2.2).

**Table A2.2 Identifying vector-related determinants of disease**

| Question | Rationale |
|---|---|
| What are the main local vectors? | It is important to identify the main vectors since control programmes need to be tailored to the characteristics of individual vectors. The species composition of vectors may change over time, for example due to climatic and environmental change and so regular re-assessment is necessary. |
| Where and when do they occur? | Vector control needs to be targeted in areas where and when the vector is present. Habitat suitability and seasonal changes in weather e.g. temperature or rainfall are big drivers of vector abundance. |
| What are the behavioural characteristics of vectors?<br><br>e.g. diurnal activity pattern, endophily, anthropophily etc. | Some control methods rely on key vector characteristics for their efficacy. For example, insecticide treated nets are effective against indoor, night time biting mosquitoes. Indoor residual spraying is effective against mosquitoes resting indoors.<br>Some vectors feed on both humans and other animals and here there may be potential to control the vector by targeting the secondary host. For example *Glossina* (tsetse flies) of the morsitans group which are responsible for transmitting Rhodesian human African trypanosomiasis may be targeted by treating cattle with insecticides.<br>The behavioural characteristics of vectors should be assessed regularly over time, since vectors may adapt their behaviour in response to control measures. |
| Where and when do the vectors breed? | Larval stages of vectors cannot run or fly away and so may be suitable targets for vector control provided that breeding sites are few, fixed and findable. It is therefore important to identify where and when vectors breed and consider vector control tools against this stage. For example, LSM could be considered against mosquito larvae for control of malaria or dengue or sandfly vectors breeding in rodent burrows could be targeted by residual insecticide. |
| Are they susceptible to insecticides? | It is important to monitor the susceptibility of vector populations to insecticides since if susceptibility is reduced vector control interventions may be less efficacious. As well as presence or absence of insecticide resistance, the intensity of resistance and specific mechanisms involved should be investigated. |

**Figure A2.1: Water storage jars provide excellent breeding sites for *Aedes* mosquitoes** (photo courtesy of S. Lindsay)

## Human-related determinants

Human related determinants can influence i) vector-human coexistence, e.g. poor housing conditions or population movement into new areas, ii) disease transmission e.g. non-use of preventive measures and iii) the infectious reservoir, e.g. population groups less resilient due to poor nutrition or co-morbidities, poor access to healthcare and effective drug treatment.

It is important for the control programme manager to identify what human related determinants are present and how these conspire to make some population groups more at risk of VBD and more likely to fuel disease transmission. These population groups should be targeted as a priority. Tackling many of these determinants will need involvement of other actors within the health sector and outside the health sector.

Table A2.3 outlines some questions that can help define what the most important human-related determinants are.

**Table A2.3 Identifying human-related determinants of disease**

| Question | Rationale |
|---|---|
| Where do the high risk groups live? | Programmes should focus disease control activities where the high risk groups live. On a large scale this information can be gleaned from the disease distribution maps included in the toolkit (Chapter 3). On a smaller scale, programmes will need to identify where there are likely hotspots of disease. This could be a dynamic situation, for example disease outbreaks in areas of economic or socio- |

| | |
|---|---|
| | political instability. On a routine basis, hotspots could be identified from health centre records, which alongside participatory mapping and community consultation is an effective method of determining risk factors. |
| Where is infection most likely to occur? | It is important to understand where transmission occurs in order to target control efforts here. Is it in their home, when they travel or where they work? This will require a deeper understanding of population movement and vector behaviour in the high risk areas. |
| Are some population groups more susceptible?<br>e.g. socioeconomic status, co-morbidities, age, sex | Low socioeconomic status is often associated with low economic resilience (e.g. availability of savings), poor nutrition and resilience against disease, poor housing conditions, high population density and overcrowding and poor sanitation and hygiene. These are all risk factors for VBD transmission. Disease control measures and support need to be targeted at these communities.<br>Co-morbidities such as malnutrition or HIV infection may make individuals more susceptible to infection with vector borne pathogens and they may suffer greater morbidity/mortality as a result. These morbidities need to be identified in the population and addressed. |
| What are local practices and attitudes towards vector-borne disease? | It is important to gain an idea of how local communities perceive and understand vector borne diseases since this may impact on their practices and behaviours. For example, this may relate to risky behaviours and practices such as storage of water which may increase dengue risk (Figure A2.1), open defecation which can increase schistosomiasis or trachoma risk or washing/bathing in contaminated waters (Figure A2.2). Alternatively, it may relate to non-use or poor adherence to preventive measures such as LLINs. |
| What is their access to diagnosis and treatment? | There are a number of factors to consider under access to treatment and diagnosis. Firstly, health service capacity varies depending on the location. In some countries, capacity in rural and remote areas will be lower than in more populated areas. Barriers to access include also awareness of disease signs and symptoms, physical distance of the health facilities (public and private) from communities or pastoralist societies, costs (e.g. travel, user fees), gender dynamics and acceptability. People may seek care in the public or private formal health sector, pharmacies and drug sellers or the traditional sector. Availability of accurate diagnosis and effective treatment is likely to differ by sector. Different groups, for example children and adults may seek care in different sectors or may use multiple sectors. The importance of compliance with medication should be emphasised. |

**Figure A2.2: Increased schistosomiasis risk due to collection of water from potentially contaminated source, Lake Victoria, Kenya** (photo courtesy of S. Lindsay)

## Environment-related determinants

Understanding the environment around VBD hotspots is important because it may allow the control programme officer to target interventions in space and time. For example, in areas of seasonal transmission LLIN distribution or IRS is best practiced at the beginning of the rainy season. Here are some questions related to the environment that will help inform you (Table A2.4).

**Table A2.4 Identifying environmentally-related determinants of disease**

| Question | Rationale |
|---|---|
| What are the local ecosystems? | Different vector species are adapted to specific ecological settings. More information on ecosystems and prevalence vector-disease complexes is given in Box 3.1. Recognising the different ecosytems allows one to get a rough idea of what vectors are present and their level of abundance e.g. Relatively low numbers of *An. gambiae* will be found in forest and urban areas as compared to rural areas. The dengue vector *Aedes aegypti* is often associated with water storage tanks and discarded containers in urban areas. |
| How is land used? | Land use for agricultural purposes can alter vector habitats and increase the risk of VBD (Figure A2.3). For example, commercial forest plantations create habitats suitable for tsetse flies. High intensity agriculture (e.g. cotton-growing areas) often associated with pesticide use can lead to insecticide-resistance in the local vectors. |

| | |
|---|---|
| | Irrigation will often increase mosquito production. This can lead to increased malaria in areas of unstable transmission, where people have little or no immunity to malaria parasites, such as the African highlands and desert fringes. In areas of stable malaria transmission, irrigation will not generally increase malaria due to changes in the dominant vector species and increased wealth generated in these areas leading to better housing and increased use of personal protective measures [354]. Urbanisation can also alter breeding sites leading to increases in VBD, including for example dengue. |
| What are the weather patterns in your area? | The life cycle of many vector species is dependent on rainfall and temperature. Identifying the seasonality of disease transmission will provide you with information about when it is best to initiate control activities. e.g. in areas of intense seasonal transmission, LLIN distribution or mass drug administration (MDA) should be done at the beginning of the rains. In the case of seasonal malaria chemoprevention (SMC), up to four doses are recommended during the malaria transmission season [353]. LSM using larvicides may have a role in suppression of larval habitats during the dry season in areas with cool seasons as in parts of Southern Africa [37]<br>In areas where epidemics may occur such as dengue or malaria, it may be possible to prepare for outbreaks by closely monitoring the rainfall patterns and vector control interventions should be in place throughout the epidemic period. |
| What is the extent and distribution of the breeding habitat? | Where do vectors breed? Is the habitat aquatic or not? Are there many breeding sites? Are breeding sites large e.g. flood plains or large scale rice irrigation? Are breeding sites relatively fixed and permament? With this information in hand you will have a better idea of whether LSM is a potential control option. |

It is the combination of interactions between pathogens, vectors, humans and the environment that determine the range and abundance of VBDs. Understanding these complex interactions allows the programme manager to understand why the diseases occur and point to ways in which to control these diseases.

**Figure A2.3: *Anopheles* breeding sites in irrigated ditches** (photo courtesy of S. Lindsay)

## Animal-related determinants

A number of VBDs are zoonoses, diseases that also occur in animals and therefore it is important to identify whether wildlife or domestic animals are carriers of vector borne pathogens. For example in parts of Ethiopia visceral leishmaniasis is transmitted by sandflies from rock hyrax to people living in villages situated on river banks or rocky hills, the natural habitats of rock hyrax. Identifying settlements at high risk of zoonotic diseases would allow targeting of disease control. Some questions that would help identify high risk communities are shown below (Table A2.5). In many cases it would be helpful to discuss these questions with local veterinarians and wildlife experts who may be able to provide up-to-date information that is locally appropriate.

**Table A2.5 Identifying animal-related determinants of disease**

| Question | Rationale |
|---|---|
| What are the common species of wildlife present in your area? | Wildlife are infected with many different pathogens, some of which may also infect humans. Birds, rodents, small mammals and ruminants can all act as reservoirs of infections for diseases of humans. For example rhodesiensis sleeping sickness can spill-over from wild ruminants (Figure A2.4), whilst gambiensis sleeping sickness is primarily a disease of people. |
| What are the common species of domestic animals? | In certain situations domesticated animals can harbour VBD pathogens. e.g. cattle can be reservoirs of infection for human trypanosomiasis. |

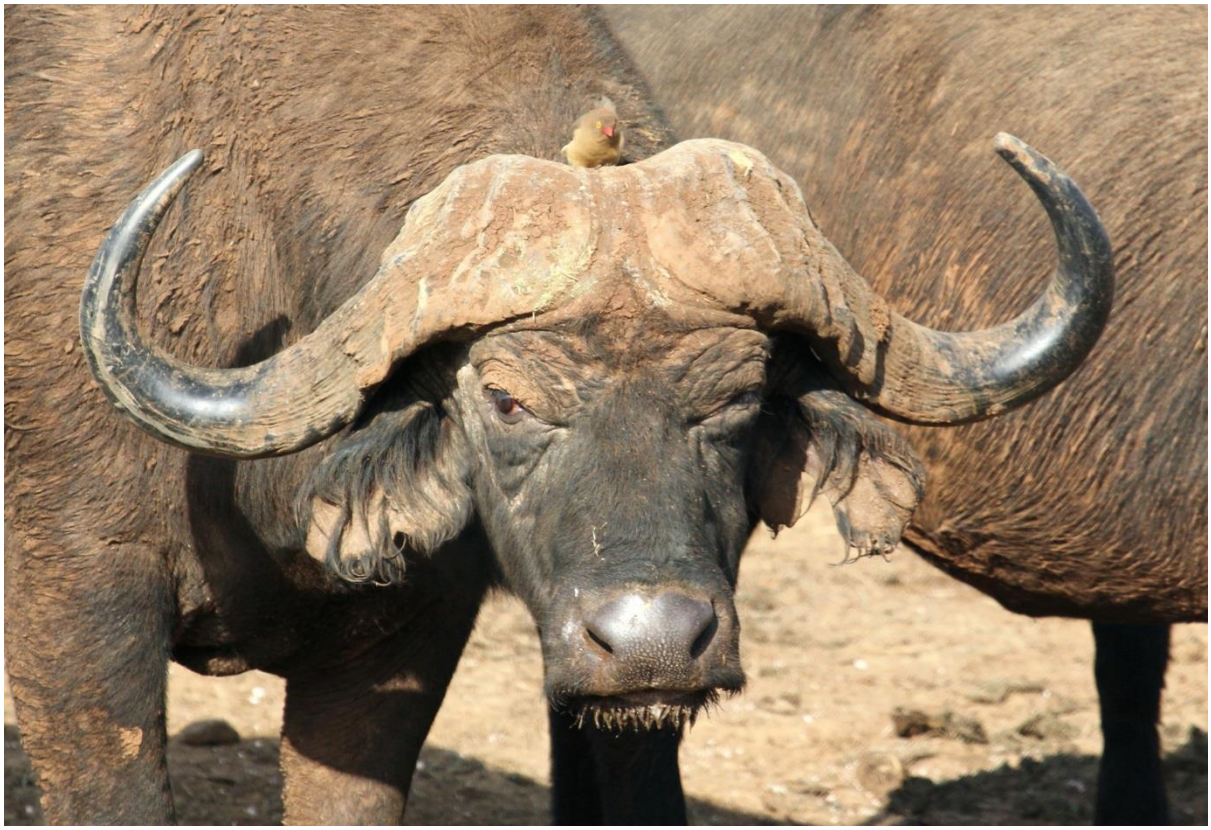


**Figure A2.4: Savannah tsetse flies commonly feed on buffalo** (photo courtesy of S. Lindsay)

# Appendix 3: Example M&E logframe for IVM programme tackling malaria and lymphatic filariasis in a rural area

| **Goal:** ***To have reduced morbidity and mortality from malaria and lymphatic filariasis in a cost effective and ecologically sound manner*** | | | | |
|---|---|---|---|---|
| **Goal** | **Area** | **Impact Indicators** | **Data type** | **Data source** |
| To have reduced morbidity and mortality from malaria and lymphatic filariasis using IVM in a cost effective and ecologically sound manner | Morbidity and mortality from malaria | Total confirmed outpatient uncomplicated malaria cases (per 1000 population per year) | Numerical | Health facility records |
| | | Under 5 mortality rate (per 1000 live births per year) | Numerical | Vital statistics |
| | | Slide / RDT positivity rate at health facility level | Numerical | Health facility records |
| | | Malaria parasite prevalence | Numerical | Representative household surveys (DHS, MICS, MIS) |
| | Lymphatic filariasis infection | Antigenaemia prevalence among endemic populations | Numerical | Household surveys |
| | | Antigenaemia prevalence among under 5s | Numerical | School or household surveys |
| | Cost effectiveness | Reduction in cost per case of disease averted per year | Numerical | Programme reports |
| | Ecological soundness | Reduction in toxic units of insecticide used per case of disease averted per year | Numerical | Programme reports |
| | Sustaining resources for vector control | Strategy in place to ensure continued mobilisation of resources for vector control | Logical | IVM Steering Committee meeting minutes |

| **Outcome** | **Outcome indicator** | **Data type** | **Data source** |
|---|---|---|---|
| Risk for transmission / effect on vector | Reduction in density of *An.gambiae* measured over specified time period at sentinel sites | Numerical | Entomological surveys at sentinel sites |
| Maintain high coverage and use of LLINs | Proportion of households with at least one LLIN | Numerical | Household survey |
| | Proportion of pregnant women sleeping under LLIN | Numerical | Household survey |
| | Proportion of U5 sleeping under LLIN | Numerical | Household survey |
| Maintain high coverage with indoor residual spraying in the targeted areas | Proportion of targeted households sprayed in past 12 months | Numerical | Household survey |
| | Proportion of targeted sleeping rooms sprayed in past 12 months | Numerical | Household survey |
| Target a high proportion of productive vector breeding sites of vectors of both diseases with environmental management or larvicide | Proportion of productive breeding sites drained or treated with larvicide | Numerical | Entomological surveys at sentinel sites |

| Output | Output indicator | Data type | Data source |
|---|---|---|---|
| Universal distribution of LLINs through appropriate channels | Number of LLINs distributed through mass campaigns | Numerical | Programme reports |
| | Number of LLINs distributed through health facilities | Numerical | Programme reports |
| | Number of nets retreated with insecticide | Numerical | Programme reports |
| | Number of BCC campaigns conducted to encourage correct use of LLINs | | |
| Indoor residual spraying in the targeted areas | Number of HHs (or rooms) sprayed in specified time frame (e.g. last 12 months) | Numerical | Programme reports |
| | Percentage of targeted HH covered by IRS | Numerical | Programme reports |
| | Volume of insecticides used in specified time frame (e.g. last 12 mth) | Numerical | Programme reports |
| Larval source management of vector breeding sites using draining or larviciding | Number / volume of breeding sites that have been drained or treated with larvicide in specified time frame | Numerical | Programme reports |

| Process | Process indicator | Data type | Data source |
|---|---|---|---|
| **INTERVENTION SPECIFIC** | | | |
| LLIN | Number of people trained in distribution / retreatment | Numerical | Programme reports |
| | Number of distribution points (community and health facilities) established | Numerical | Programme reports |
| | Number of LLINs guidelines distributed | Numerical | Programme reports |
| | Number of meetings held with stakeholders | Numerical | Programme reports |
| | Number of mass distribution campaigns implemented | Numerical | Programme reports |
| IRS | Number of target HHs mapped | Numerical | Programme reports |
| | Number of spray operators trained | Numerical | Programme reports |
| | Number of IRS guidelines distributed | Numerical | Programme reports |
| Larval source management | Number of productive breeding sites identified | Numerical | Programme reports |
| | Number of larviciding operators trained | Numerical | Programme reports |
| | Number of LSM guidelines distributed | Numerical | Programme reports |
| **IVM / SYSTEM SPECIFIC** | | | |
| Training on IVM | Number (and percentage) of staff trained in IVM | Numerical | Programme reports |
| Human resources | Number (and percentage) of staff with job descriptions that make reference to vector control | Numerical | Programme reports |
| Advocacy, communication and social | Number (and percentage) of sites at which campaigns on | Numerical | Programme reports |

| | | | |
|---|---|---|---|
| mobilisation | behavioural change on vector control were conducted | | |
| | Number (and percentage ) of villages in which communities have been mobilised for vector control | Numerical | Programme reports |
| Planning and implementation | Number (and percentage) of sentinel sites with functioning vector surveillance and insecticide resistance monitoring | Numerical | Programme reports |
| Operational research | Number (and percentage) of operational research priorities on vector control that have been addressed | Numerical | Programme reports |
| | Number of operational research outcomes on vector control that have been used in implementing programmes | Numerical | Programme reports |

| **Input** | **Input indicator** | **Data type** | **Data source** |
|---|---|---|---|
| **INTERVENTION SPECIFIC** | | | |
| LLIN | LLIN guidelines developed | Logical | Programme reports |
| | Number of LLINs purchased | Numerical | Programme reports |
| | Number of retreatment kits purchased | Numerical | Programme reports |
| IRS | Number of spray equipment purchased | Numerical | Programme reports |
| | Volume of insecticide purchased | Numerical | Programme reports |
| | IRS guidelines developed | Logical | Programme reports |
| Larval source management | LSM guidelines developed | Logical | Programme reports |
| | Volume of larvicide purchased | Numerical | Programme reports |
| | Number of spray equipment purchased | Numerical | Programme reports |
| **IVM / SYSTEM SPECIFIC** | | | |
| Policy | National IVM policy in place | Logical | Programme reports |
| | National policy on pesticide management in place | Logical | Programme reports |
| | National strategic and implementation plan on IVM in place | Logical | Programme reports |
| Institutional arrangements | National steering committee on IVM in place | Logical | Programme reports |
| | National coordinating unit on vector control in place | Logical | Programme reports |
| Capacity building | Certified training courses on IVM and judicious use of pesticides in place at national or regional level | Logical | Programme reports |
| Organisation and management | Standards for professions and careers in vector control and public health entomology in place | Logical | Programme reports |